

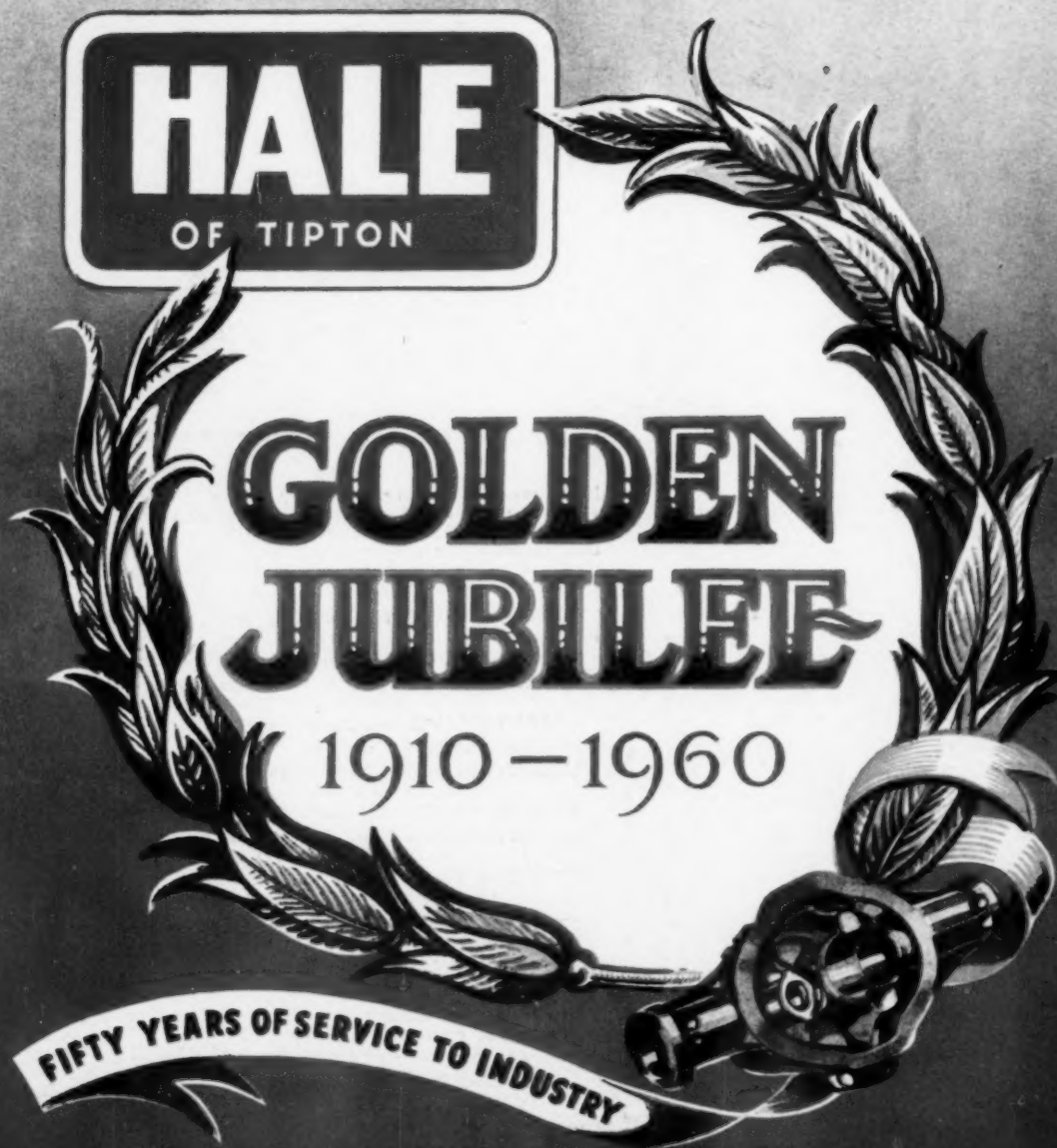
# METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 62 No. 369

JULY, 1960

Monthly: Two Shillings and Sixpence

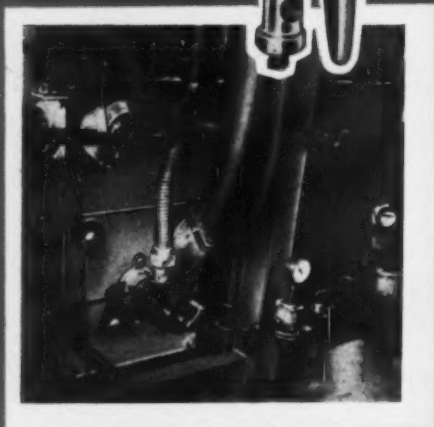
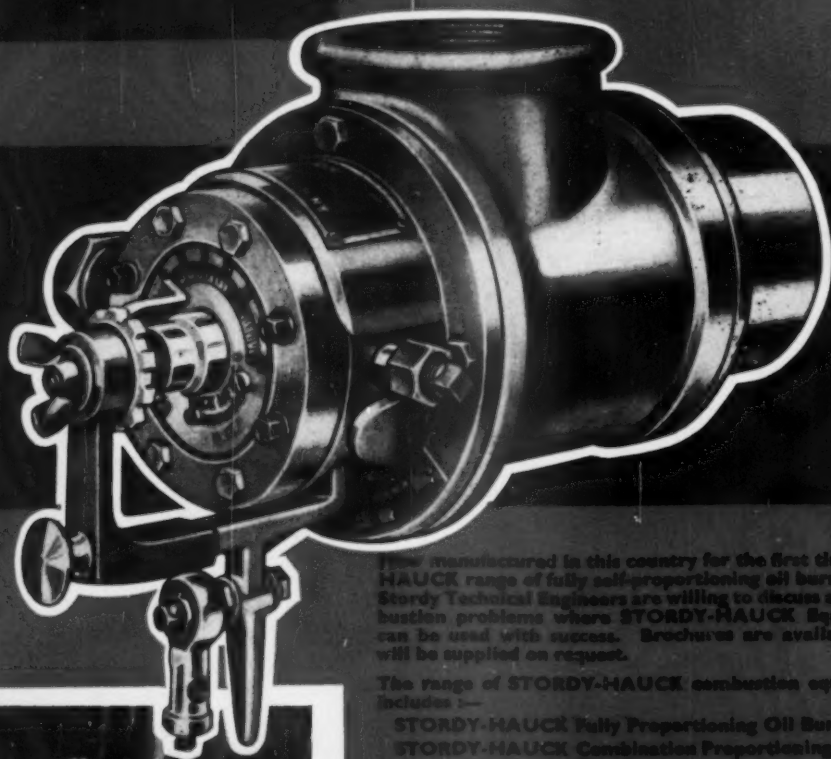


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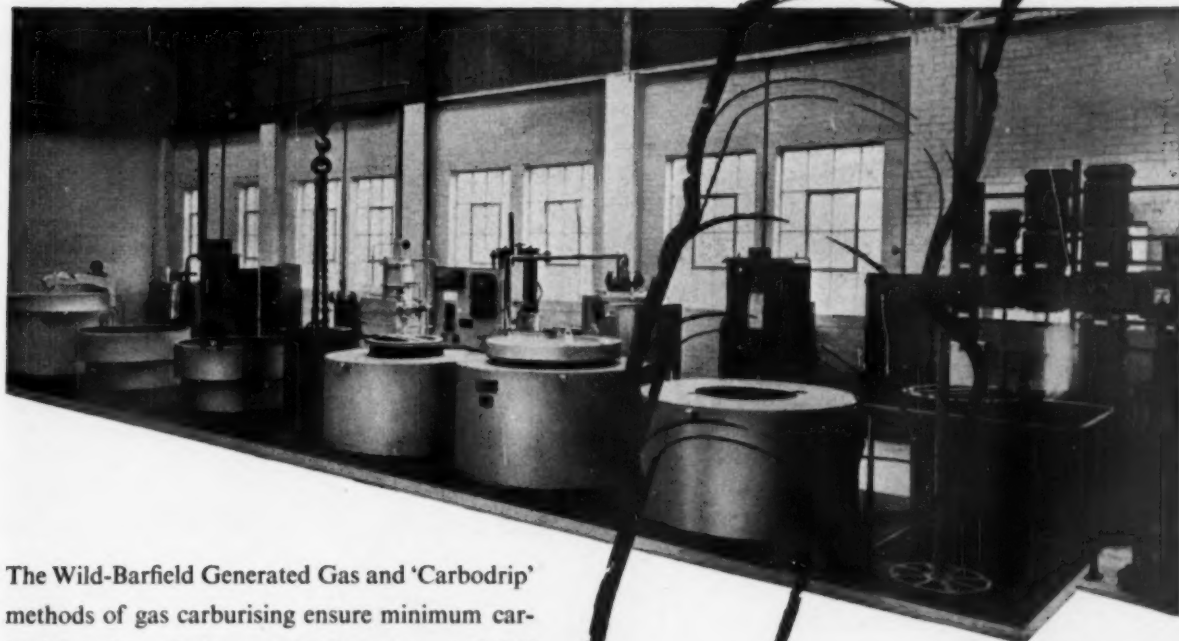
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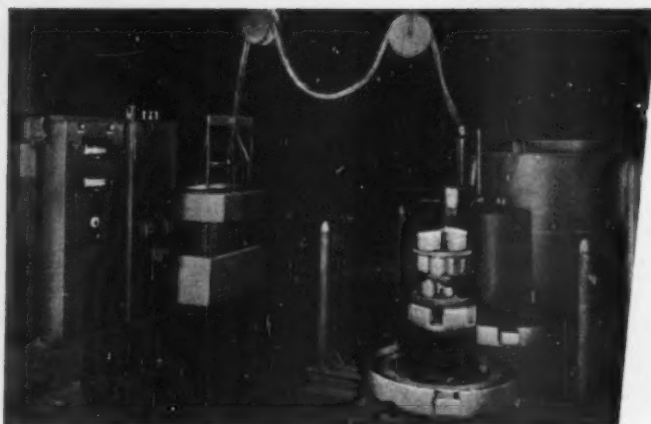
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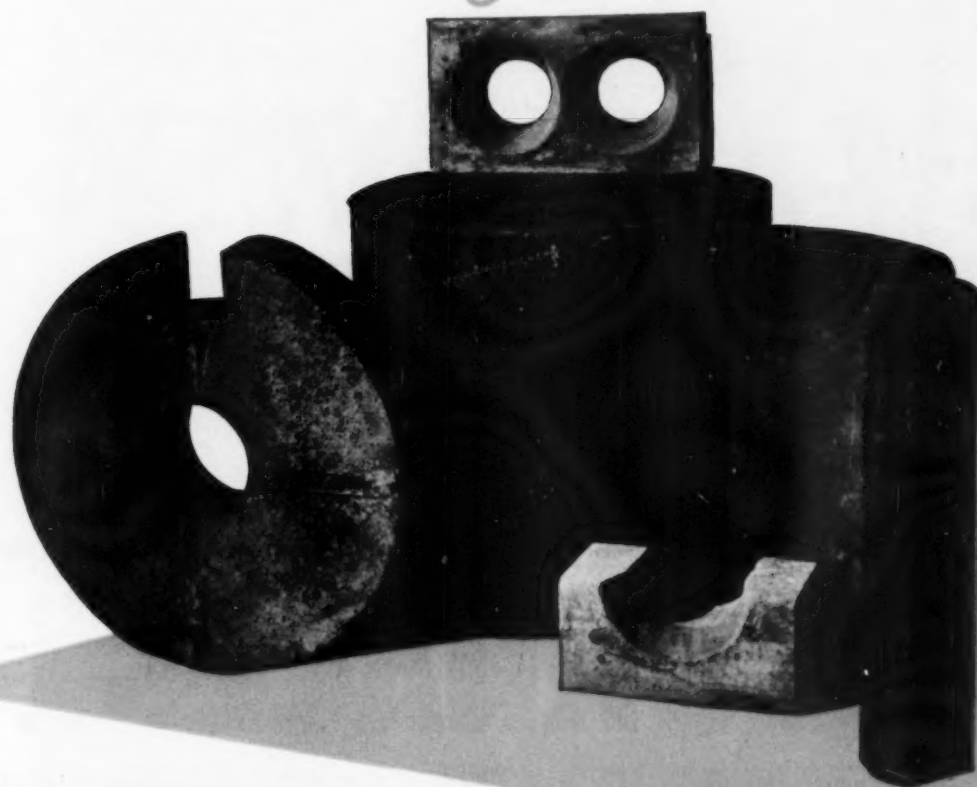
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<b>No. 17</b>	Dry	+1750°C	Hydraulic	1200°C	1700°C	160
<b>No. 18</b>	Dry	+1750°C	Hydraulic	1200°C	1800°C	160
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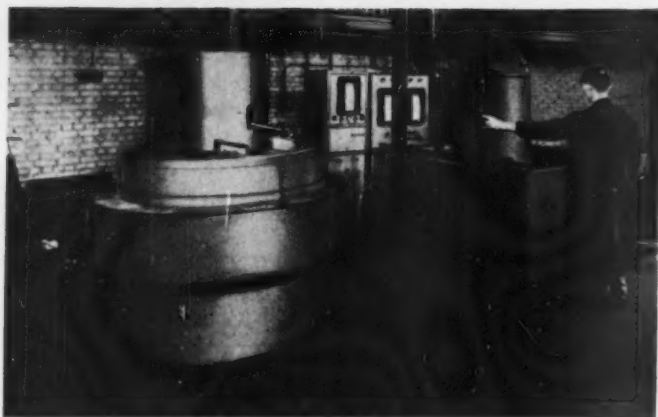
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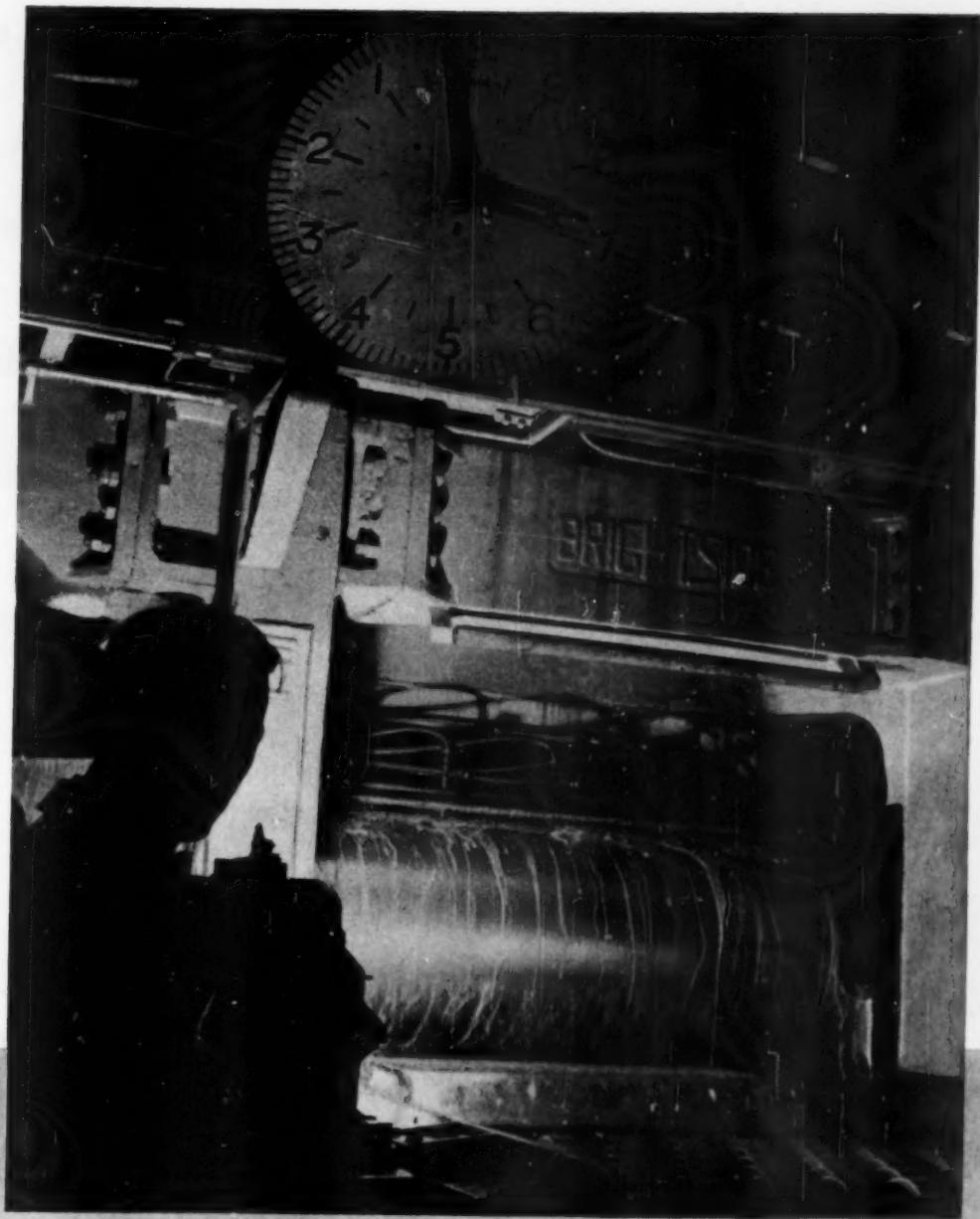
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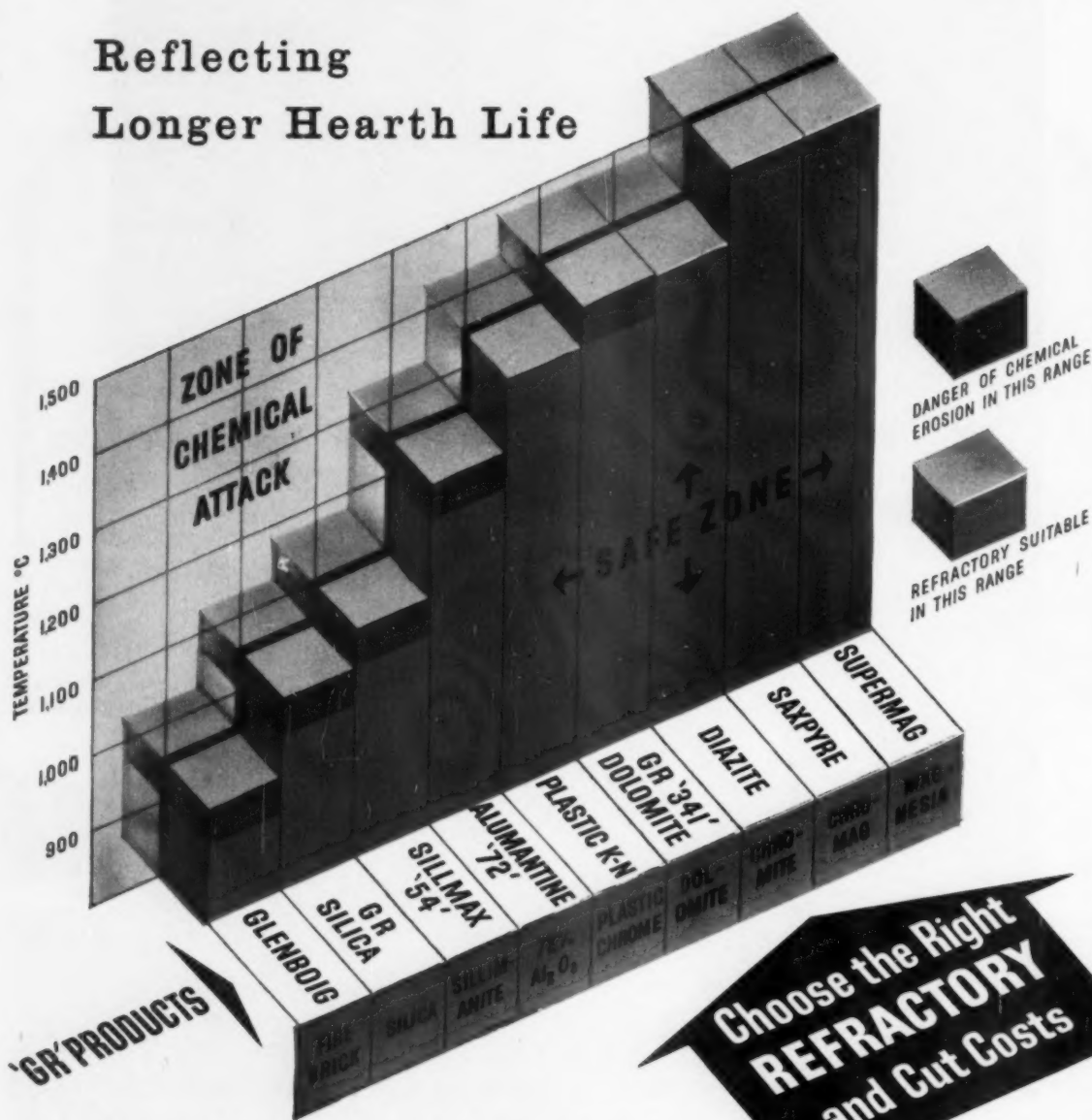
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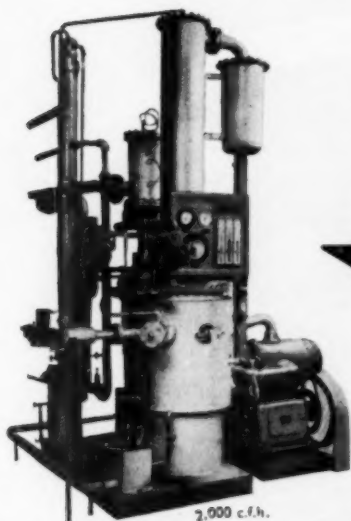
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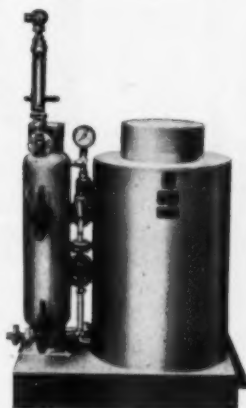


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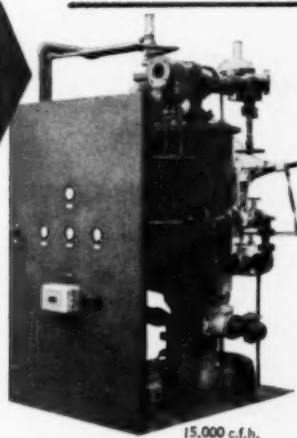
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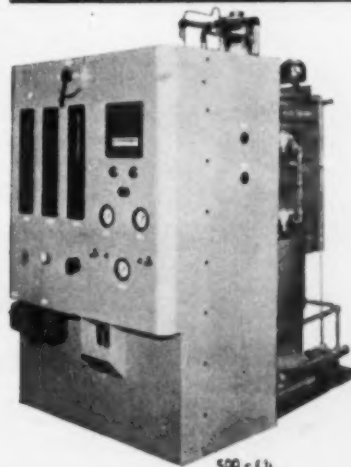
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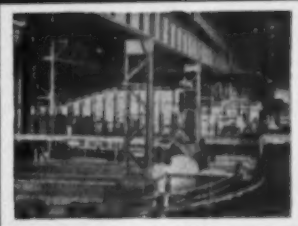
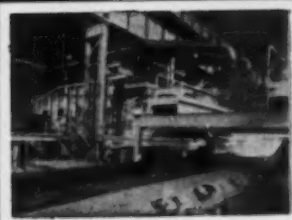
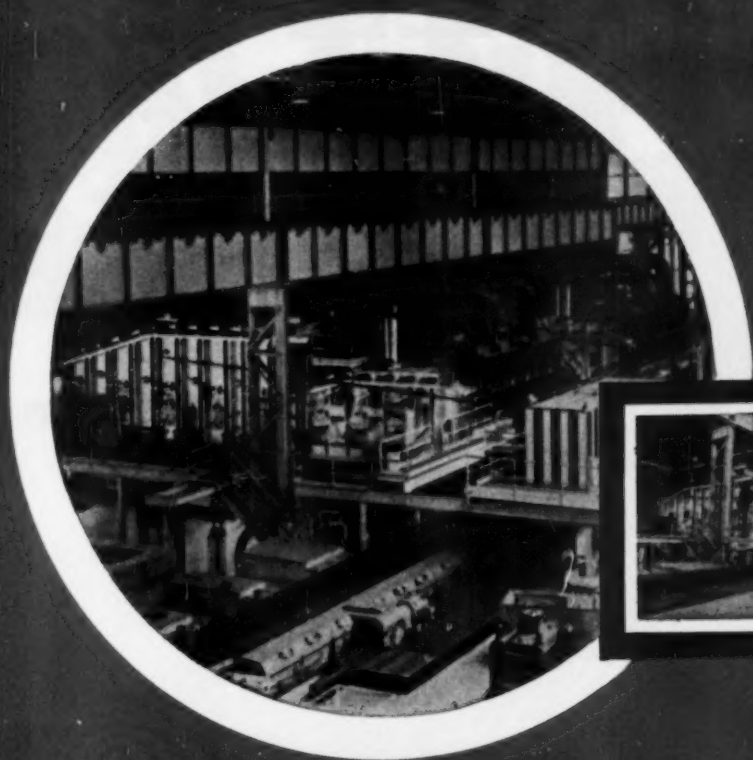
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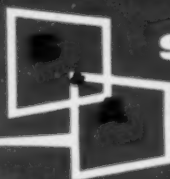
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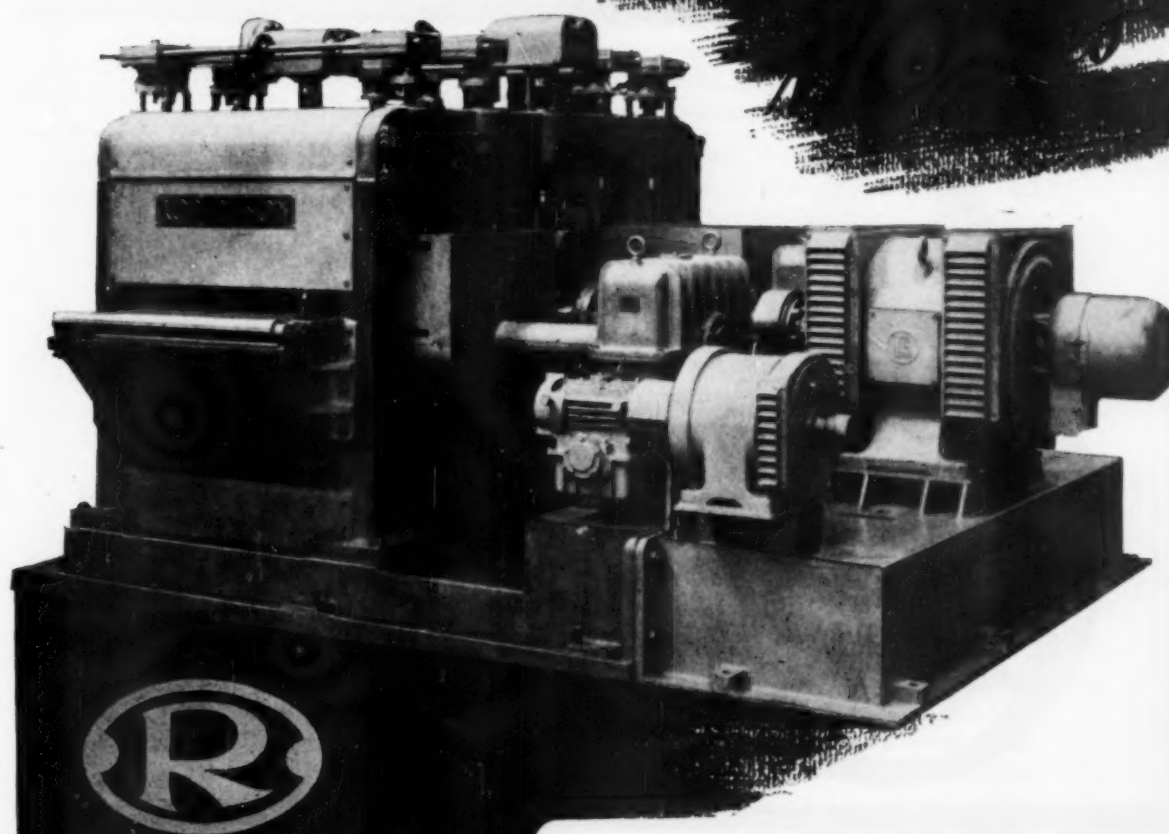
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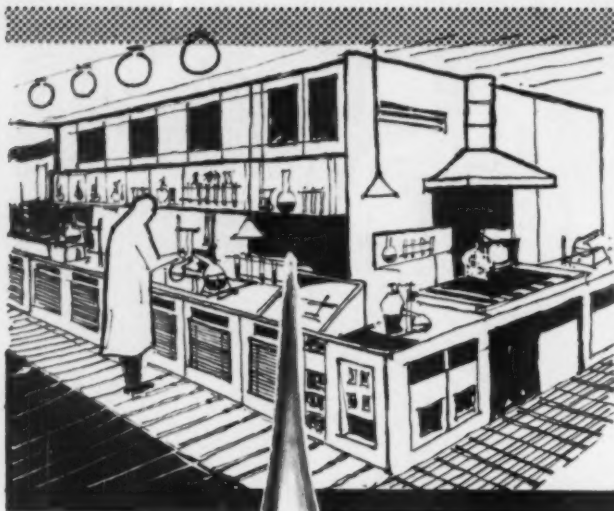
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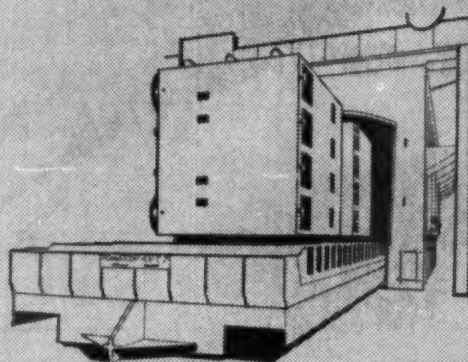
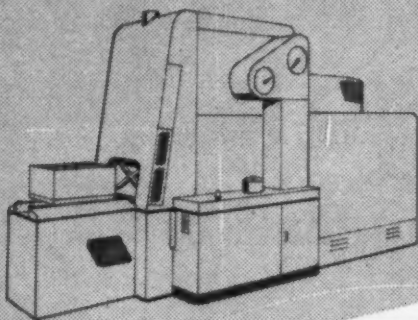
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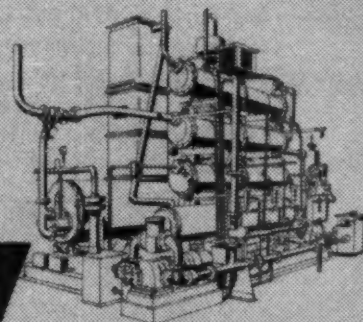
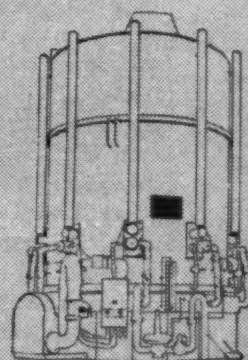
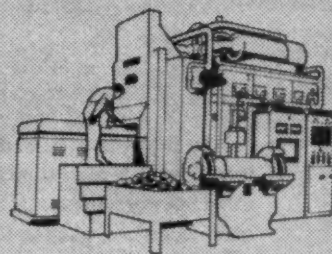
Growing public awareness and official legislation is making increasing demands on manufacturers and suppliers as regards the quality and purity of their products and services. Few people except, of course, those intimately concerned, realise that in the end this means it is the Analytical Chemist who is responsible for ensuring standards are met and bettered.

In fact, it is the Analytical Chemist's ceaseless search for improved techniques that makes these higher standards realistic, as no legislation or published standard can itself ensure purity unless an analytical method exists which is sufficiently sensitive and accurate on all occasions, and for which there is the instrument aid available to make it practically useful. For companies engaged in the development of instruments aimed at making the Analytical Chemist's task lighter, it is very difficult to talk to enough people in the field to find out what is nearest and dearest to their hearts in this respect. However, Southern Instruments Limited of Camberley have set themselves this task and have recruited a team to tackle it. Initially concentrating in the electro-chemical field, this company is building up a range of aids which will be designed to provide the benefits of convenient operation, saving in time and money, and the employment of staff appropriate to the job in question. Their fully equipped laboratory led by J. Hetman, F.R.I.C. is constantly and confidentially dealing with a vast range of Analytical matters for Analysts who feel for example, that Polarography may have advantages to offer them. This enables the chemist to be fully satisfied that his requirements are met beforehand. This service is free, and open to anyone, and whilst it is not claimed that Southern Instruments know all the answers, they do know many of them. Future electro-chemical products will also be backed by an Applications Advisory Service.

Conscious of the absolute necessity of instruments embodying chemist user requirements, Southern Instruments have appointed Mr. H. M. Davis B.Sc., A.R.I.C. A. Inst. P. as Chief Engineer, Analytical Instruments Department. Well known for his design of the Cathode Ray Polarograph when at the Ministry of Supply, Mr. Davis now leaves the United Kingdom Atomic Energy Authority Research Group at Woolwich to take his unusual combination of chemistry, physics and electronics to Camberley. Southern Instruments wants to hear from any Analyst who has ideas about the Service and products he requires from Instrument companies and who is conscious of a desire to look into alternative methods of analysis, routine or otherwise.



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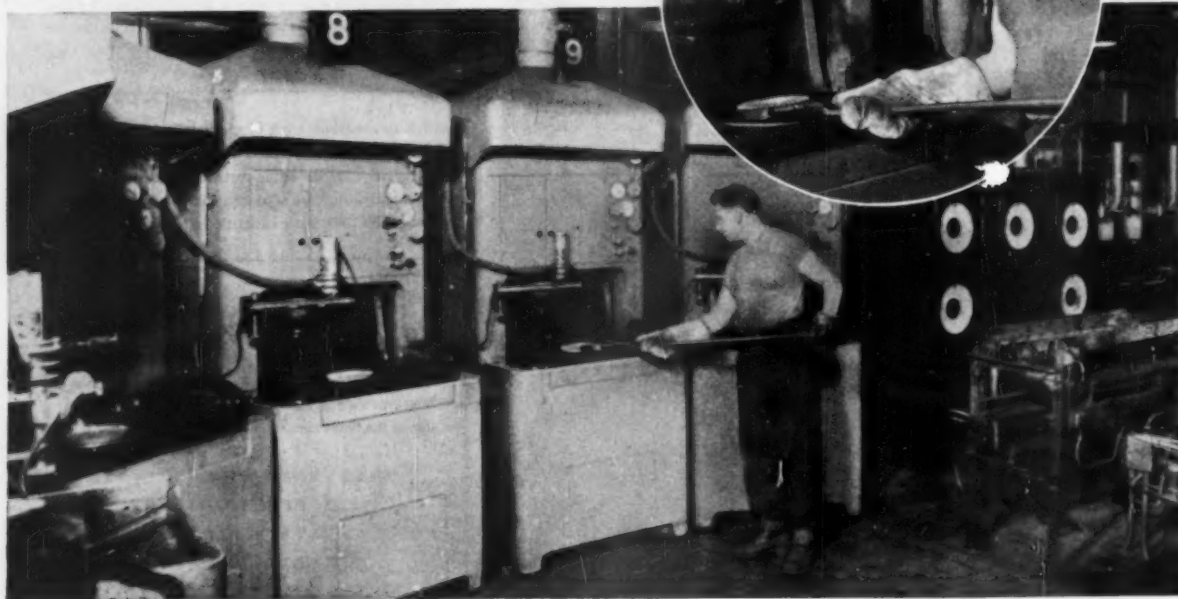
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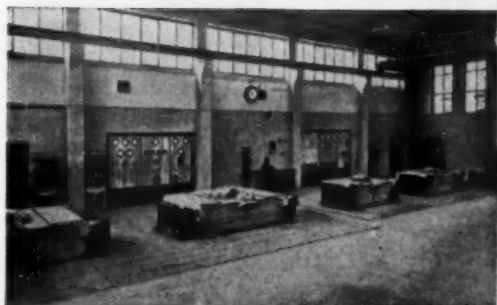
Honeywell Controls Limited,  
Ruislip Road East, Greenford,  
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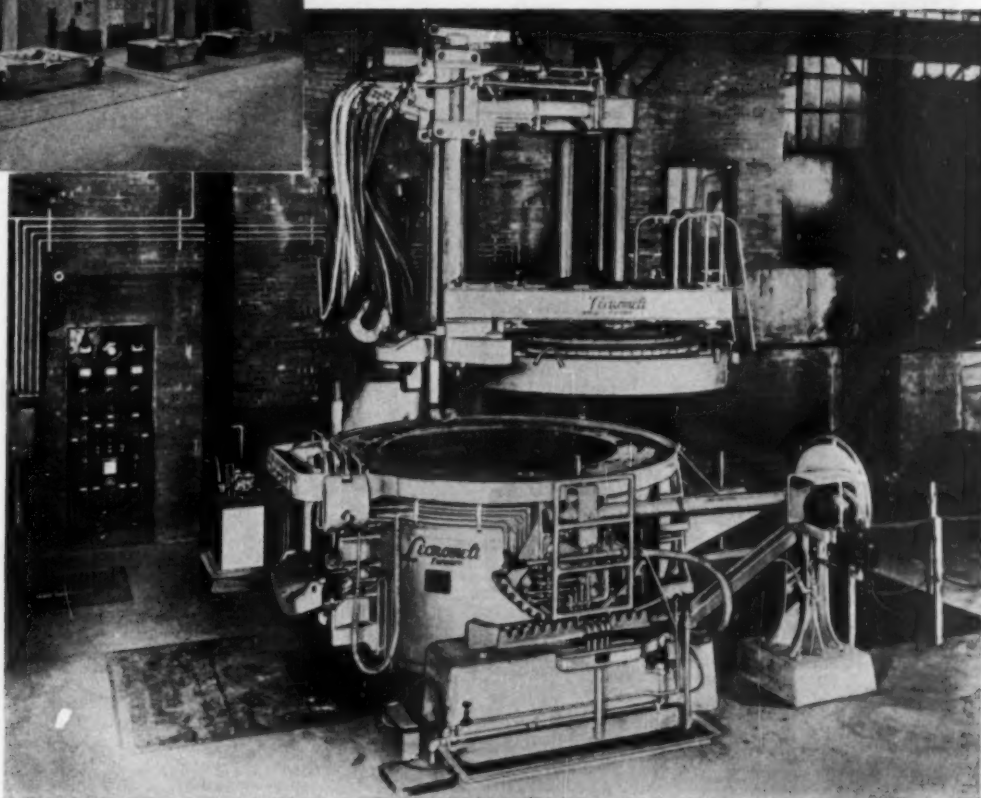


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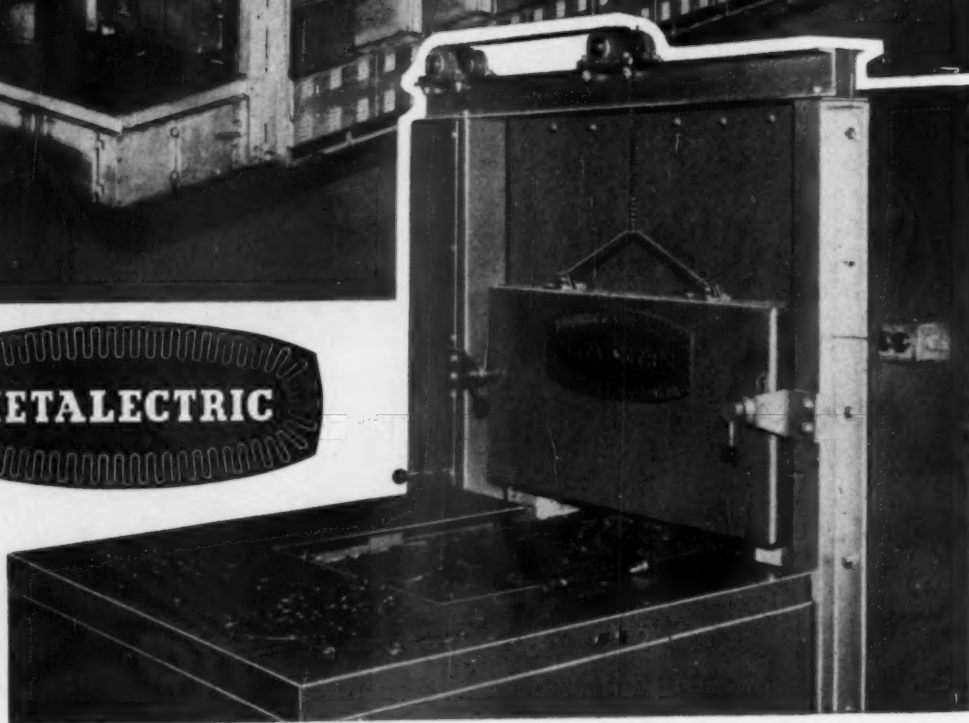
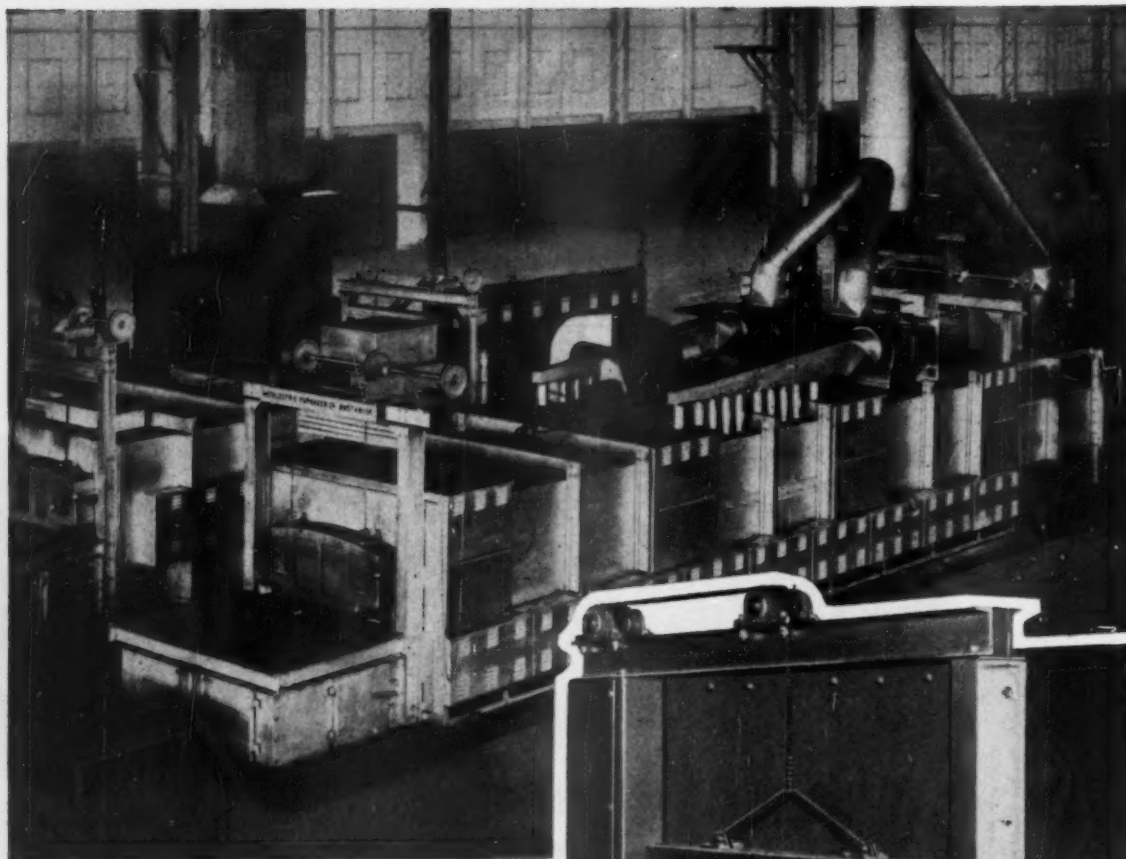


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GWB 243



## Heat treatment of forgings

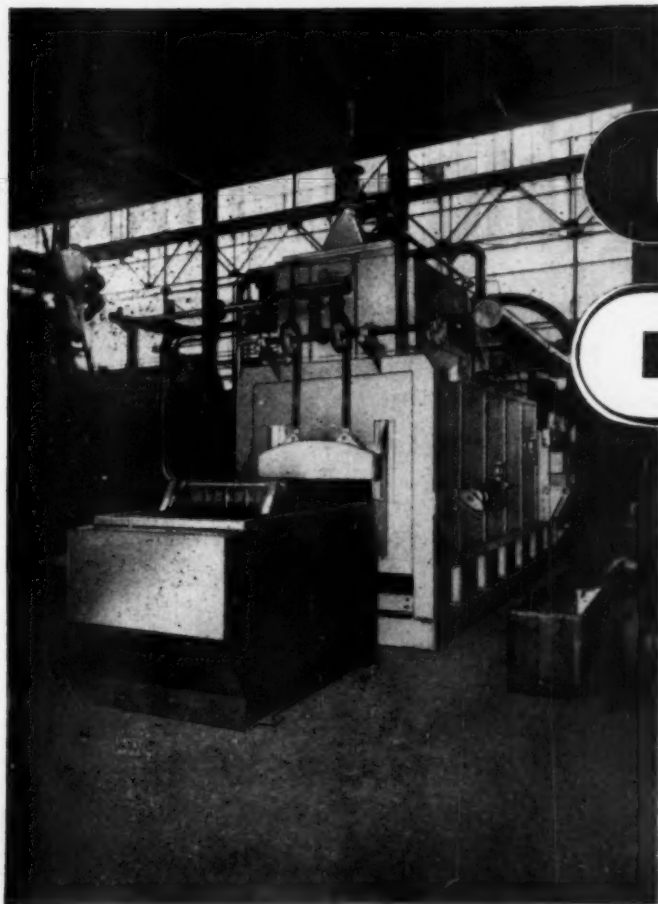
The lower furnace is the latest of many Metaelectric installations at Garringtons Ltd., Bromsgrove. The plant, which includes endothermic atmosphere equipment, is used for clean hardening and tempering of small tools. It supplements other installations such as the heavy duty furnaces shown in the upper photograph, which are used for the heat treatment of miscellaneous forgings.

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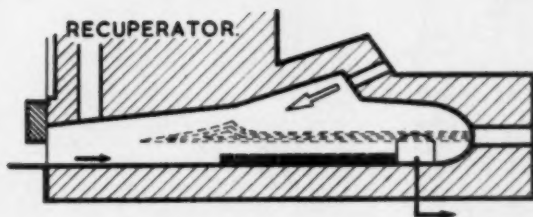
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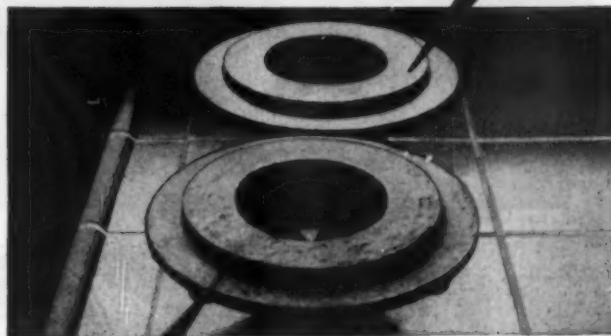
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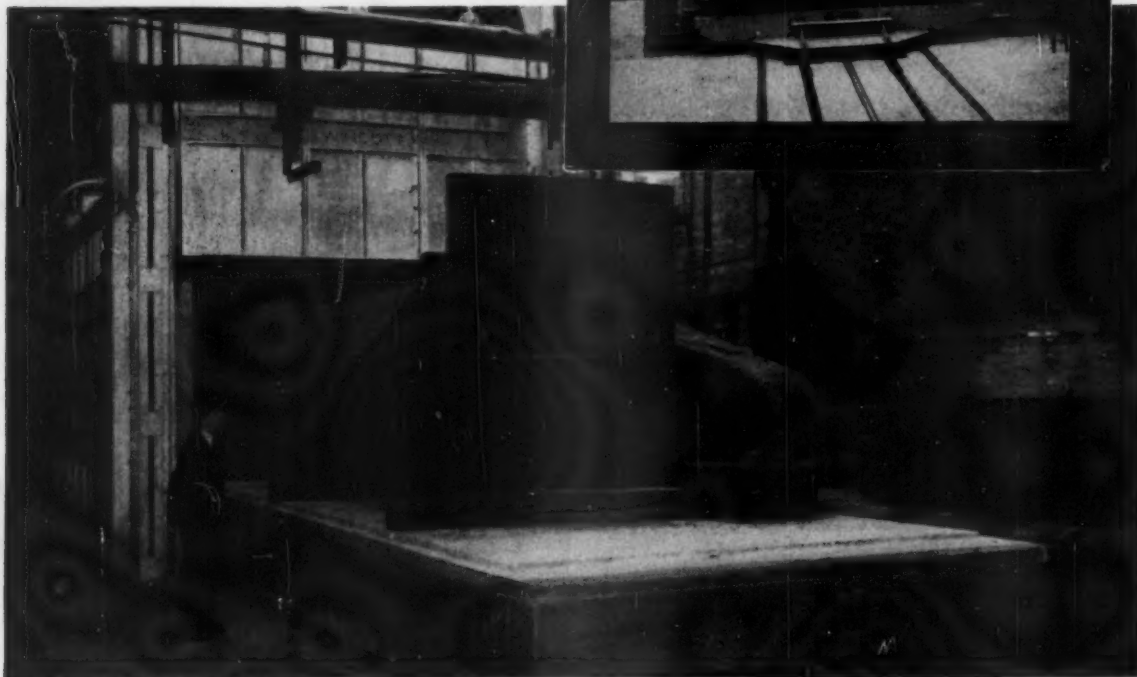
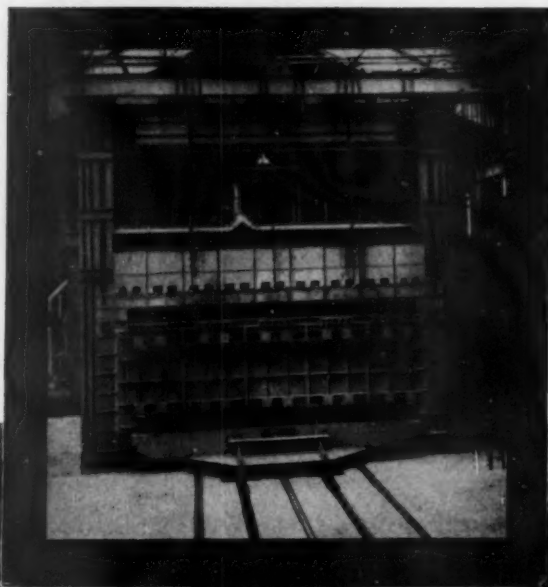
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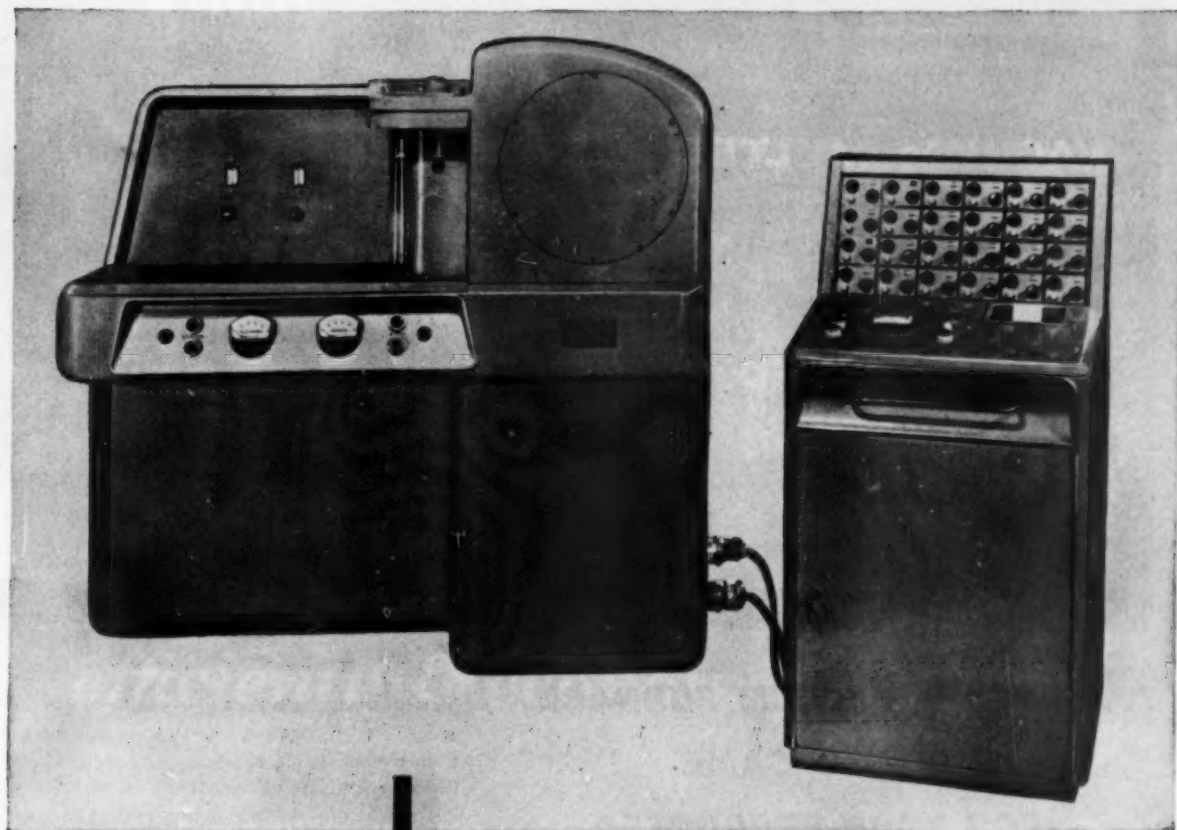
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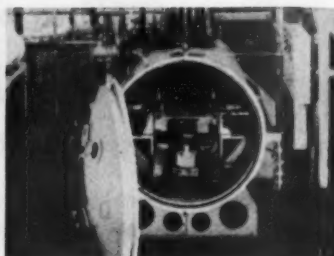
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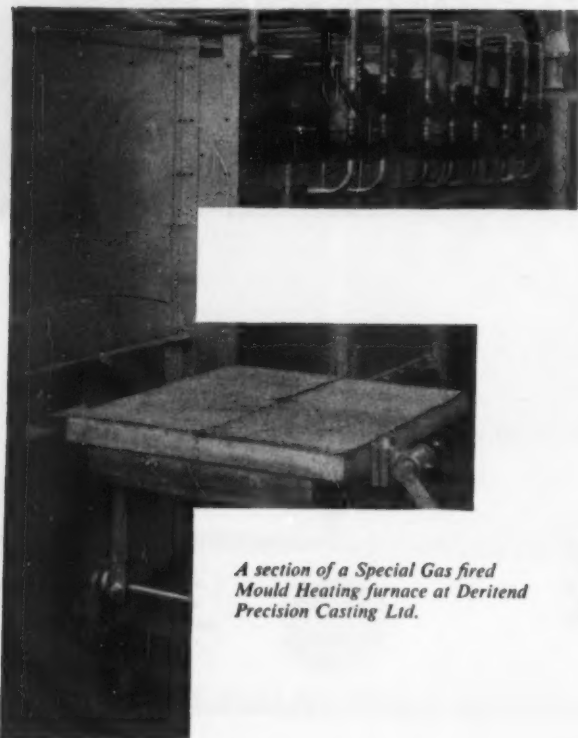
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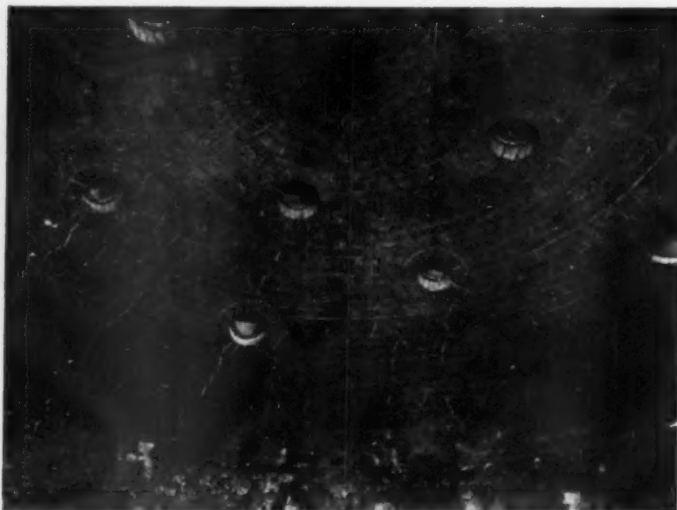
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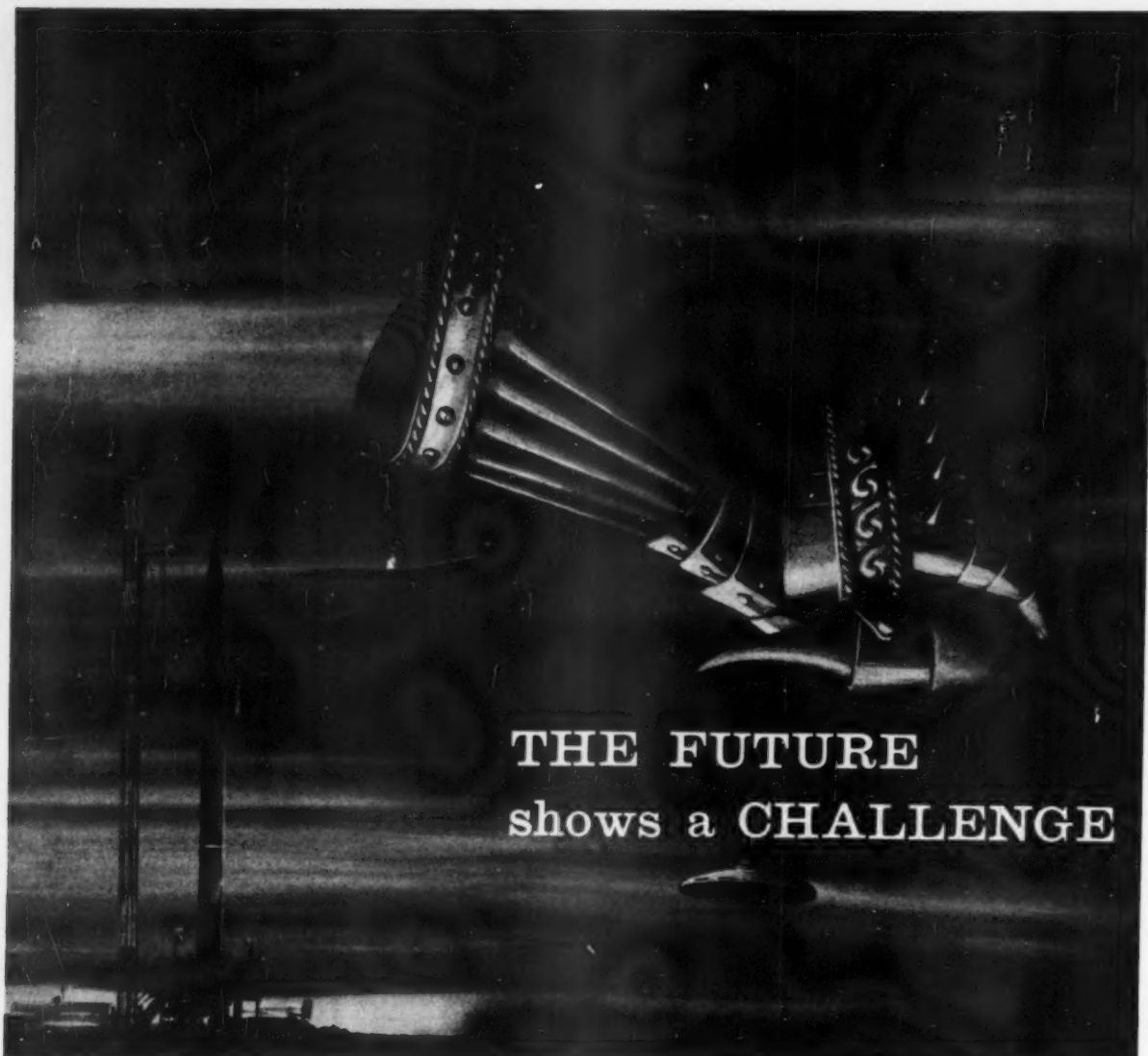
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THE BRITISH JOURNAL OF METALS  
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR JULY, 1960

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# METALLURGIA

THE BRITISH JOURNAL OF METALS  
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JULY, 1960

Vol. LXII. No. 369

## The European Coal Situation

THE gravity of the coal situation, caused by the excess of supply over demand, is emphasised in the Annual Report of the O.E.E.C. Coal Committee published under the title "The Coal Industry in Europe." The glut on the coal market which has lasted for more than two years, is, the Committee points out, in sharp contrast with the shortage which, with a few brief exceptions, was felt from 1945 to 1957. This sometimes acute shortage and its persistence had led to the conclusion that one of the features of the energy economy of the Western European countries in the next fifteen to twenty years would be a steady increase in coal requirements.

This situation has now completely changed, and is marked by an excess of supply over demand and an unprecedented accumulation of pithead stocks, which rose from 16 m. tons in December, 1957, to 68 m. tons in December, 1959. This figure in itself is enough to demonstrate the gravity of the crisis now facing the coal industry. In the two years 1958 and 1959, the apparent coal consumption of O.E.E.C. Member countries fell by about 62 m. tons, or nearly 6% per annum. Consumer stocks, which in general move in inverse ratio to producers' stocks, fell from 42 m. tons in December, 1957, to 33 m. tons in December, 1959.

The radical change in the coal market over the last two years naturally led the Committee to seek to define its causes. The Coal Committee believes that the present recession in coal is no doubt due to structural factors, although associated cyclical factors connected with the 1958 recession and exceptional climatic conditions have certainly helped. According to calculations made by the Secretariat, the fall of 38 million tons in the demand for coal in 1958 can be explained by the recession in industrial activity (11 million tons), the switch from coal to oil (12 million tons), higher fuel efficiency (6 million tons), the mild winter (5 million tons) and exceptionally good hydro-electric conditions (4 million tons). The demand for European coal was, moreover, also affected by imports from countries outside the O.E.E.C. area.

In spite of great difficulties in disposing of output, the coal industry made every effort to keep up production in 1958, and output for the O.E.E.C. countries as a whole fell by 2% only. In 1959, however, the rise in stocks forced producers to make a further 4-6% cut in output.

In 1959, several countries took steps to try to bring production into line with demand, such as short-time working, suspension of recruitment and a policy of not replacing workers leaving the mines. This resulted in a reduction, between January, 1958, and the end of December, 1959, of 140,000 underground workers out of a registered total of 1,200,000. However, these same years (1958 and 1959) also witnessed an increase (18.6% in the Community and 10.8% in the U.K.) in output per underground shift in the European coalmines.

The Committee lists the steps taken by individual countries to palliate the coal crisis. In addition to short-time working and the suspension of recruitment already referred to, mention may be made of the following steps, although they have not been uniformly applied by all producer countries: restriction of imports from the U.S., lower coal prices, additional taxes on fuel oil, closing down certain marginal mines, and freezing pithead stocks. Imports from the U.S. fell from 44 million tons in 1957 to 17 million tons in 1959.

Notwithstanding these steps, and in contrast to the more favourable trend recorded in the other sectors of the economy, the coal market was still showing only slight signs of improvement at the beginning of 1960. The Coal Committee therefore considered whether previous forecasts about the future demand for coal should not be revised completely. The Committee takes the view that in 1960 demand is likely to be stable at the present figure. It does not follow that a balance between supply and current demand will necessarily be achieved in 1960. That will depend on the outcome of the measures which the producers in the different countries are taking to adjust production, and some further increase in stocks in 1960 may therefore be unavoidable.

As regards the probable trend up to 1965, there is no reason to believe that demand for coal will fall as compared with 1959. Industrial activity is already picking up after the recent lull, and if this expansion continues, as may be hoped, the level of industrial activity in 1965 can be expected to be appreciably higher than it is now, which would entail a correspondingly higher demand for energy in one form or another. Because of the underlying trend to the use of other fuels, in particular oil, one would expect much of the increase in energy demand to be taken up by fuels other than coal. But although the relative share of coal in the total fuel account will decline, as it has been doing for many years, the absolute demand for coal may be at least as high as now, if not higher.

If coal is produced at acceptable, i.e. competitive, prices, in a market of fair competition, it will continue to command large markets in the coming years. The watchword must therefore be efficient production (rather than production at any price) and concentration on the more profitable mines. This will open the way to a reorganisation of the European coal industry, which will result in the closing down of a number of marginal mines and sometimes the closing down of certain seams that have proved too difficult to work.

The danger is that production, and particularly production capacity, may be reduced more than is necessary, which in time could lead to a recurrence of coal shortage, for the closing down of a mine is an irrevocable act. It is for this reason that the Committee considers that these actions should be reviewed periodically in the light of the latest trends. It must not, in any event, start from the assumption that the situation will get worse, but must rather be inspired by the firm

determination to stop that happening by strengthening the competitive position of coal with all possible speed, without exposing workers in the industry to undue hardship.

In an industry such as coal which employs abundant labour (labour accounts for about 60% of production costs), short time working and the closing down of pits raise serious social problems for the workers and areas in question. So long as there are possibilities of re-employing the workers in other industries, the problem is not insoluble, but in mining areas where economic life centres exclusively on coal, resettlement may prove difficult, and it may be necessary to introduce new industries.

## Personal News

MR. A. STEPHENS has rejoined Honeywell Controls, Ltd., as senior flow engineer at the company's Greenford (Middlesex) head office. Mr. Stephens served a four-year apprenticeship with the Ministry of Supply, and his experience in this field has been gained with Electroflo Meters Co., Ltd., George Kent, Ltd., Honeywell Controls, Ltd., and Humphreys and Glasgow, Ltd. (on the Chesterfield underground gasification project). Mr. R. W. H. VIVIAN has been appointed at the Greenford (Middlesex) head office of Honeywell Controls, Ltd., to specialise on application engineering using the company's electric miniature instrumentation, which is being introduced this year in the United Kingdom. Mr. Vivian will shortly leave this country for a brief study of United States' experience in this field.

CAPT. F. T. BOSWELL, R.N. (retd.), who joined Samuel Fox and Co., Ltd., a subsidiary of The United Steel Cos., Ltd., earlier this year as assistant welfare officer has now been appointed welfare officer. He succeeds MAJOR W. G. A. CARRINGTON, who has retired after 17 years' service.

MR. A. CLARK, previously general manager of British Driver-Harris Co., Ltd., has been appointed a director. Mr. Clark joined the company in 1929 and worked in the laboratory for fifteen years. In 1944 he moved to the production side, becoming assistant works manager of the cable department. Then, in 1951, he transferred to high nickel alloy production, in three years reaching the position of general manager.

MR. T. WINTREP, sales manager (engineering) of Distingu Engineering Co., Ltd., a subsidiary of The United Steel Cos., Ltd., has been appointed purchasing and contracts manager. He will be responsible to the commercial manager for the purchasing activities of the company and for the placing of all sub-contracted work. MR. J. TONKS, senior draughtsman, succeeds Mr. Wintrup as sales manager (engineering).

MR. W. E. DUCKWORTH has been appointed head of the Metallurgy (General) Division of the British Iron and Steel Research Association. A Cambridge graduate, Mr. Duckworth joined the Nelson Research Laboratories of the English Electric Co. in 1946 to study metallurgical problems associated with heavy electrical switchgear. In 1947 he moved to British Insulated Callender's Cables to work in their Prescott laboratories on corrosion and fatigue problems in cables and overhead electrical fittings. In 1949 he joined the Glacier Metal Co. as

In conclusion, the Committee rounds off its Report with an analysis of the trend of coal consumption over the next few years by sector. In all probability, certain sectors which are large consumers, such as iron and steel and thermal power stations, will need more coal in the coming years. In certain other sectors, such as railways and gasworks, the marked although gradual trend away from coal will persist. In other industries—and in the domestic sector where competition between coal and petroleum products is particularly keen—demand will depend mainly on prices but also on utilisation techniques and convenience. As regards the trend of demand over the next five years, the pattern of fuel consumption is so shifting that forecasts can only be conjectural.

research investigator and in 1955 was appointed manager of a research department which included a chemical laboratory, metallurgical and process control sections and an operational research section; he became manager of an operational research department in 1959. PROFESSOR G. WESLEY AUSTIN, O.B.E., will continue to act as consultant to the division.

MR. G. L. BAILEY, C.B.E., director of the British Non-Ferrous Metals Research Association left on July 17th for the Rhodesian Copperbelt where he was to spend a fortnight visiting the smelters and refineries of the Rhodesian Selection Trust group of companies and the Anglo American Corporation of South Africa.

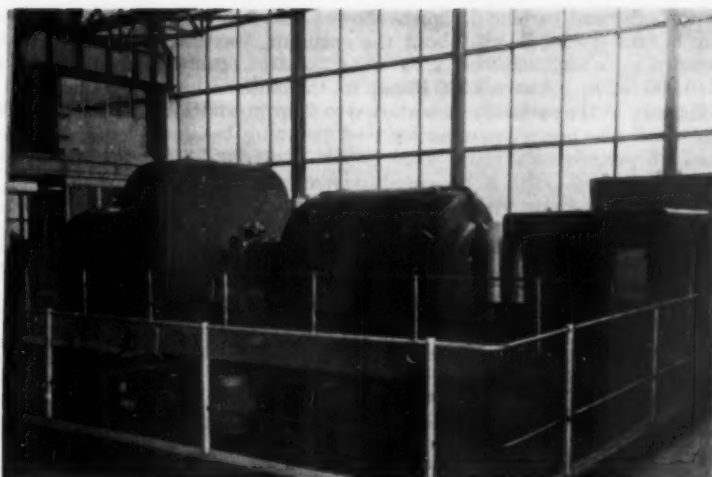
MR. T. B. ADKINS, general manager of the Ore Mining Branch of The United Steel Cos., Ltd., for the past thirteen years, retired on June 30th after 56 years with the company. He is succeeded by MR. D. R. WARD JONES, who was previously assistant general manager of the Ore Mining Branch. LT.-COL. P. F. BENTON JONES, who is managing director (mining and carbonisation) of United Steel, relinquished the position of general manager of United Coke and Chemicals Co., Ltd. on June 30th. MR. A. L. CURTIS, operations manager of that company, became general manager on July 1st.

THE following organisational changes in The Mond Nickel Co., Ltd., and its subsidiary company, Henry Wiggin and Co., Ltd., became effective as from July 1st, 1960: MR. G. ARCHER has relinquished his position as chairman of Mond and Wiggin to become president of the two companies; he is succeeded as chairman by MR. I. A. BAILEY. DR. L. B. PFEIL has been appointed vice-chairman of Mond and MR. J. O. HITCHCOCK managing director of Mond and deputy chairman of Wiggin. MR. H. W. G. HIGNETT has been appointed managing director of Wiggin.

APPLEBY-FRODINGHAM STEEL Co., branch of The United Steel Cos., Ltd., have made a number of new appointments in view of current developments in the rolling mills and the plan for installing a rod/bar mill. MR. R. Wogin, formerly manager of the Appleby melting shop is now assistant works manager (steel): in this position he will have both general and specific duties delegated to him by MR. W. JACKSON, works manager (steel). MR. R. JOHNSON has been appointed melting shops manager, responsible for both the Appleby and Frodingham melting shops, together with the basic slag plant and the refractories section. MR. A. F. JESSOP and MR. W. L. WILLSHER have been appointed managers of the Appleby and Frodingham melting shops, respectively.

# New Margam Power Plant

## Britain's First Benson Boiler



The high pressure turbo-alternator

**A**N outstanding event in large scale steam generating practice has taken place at the Margam Works of The Steel Company of Wales with the installation of Britain's first Benson "once through" boiler. The introduction of this boiler, together with a back pressure turbo-alternator, is a major advance in industrial steam usage in this country.

The original Benson boiler was developed in Germany from designs patented in Britain by Mark Benson 38 years ago. The design is based on the principle of forced water circulation through continuous preheater, evaporator and superheater tube banks. The present boiler, which was designed and built by Simon Carves, Ltd., has been added as an extension to the Margam "B" power station. It is fired by blast furnace gas and is capable of generating 240,000 lb. of steam per hour at a pressure of 3,300 lb./sq. in. and a temperature of 1,060° F., with reheat to 836° F. Such advanced steam conditions have only before been used commercially at a few major power stations and industrial steam plants on the continent.

The Benson boiler will power what is believed to be the highest pressure turbine ever manufactured in Britain. Built by Richardsons Westgarth, Ltd., the turbine will produce an alternator output of 9.5 MW. and will therefore result in a considerable saving of electricity now being imported from the national grid. Normally 200,000 lb. per hour of exhaust steam from the turbine will, after reheating, be discharged into the existing 650 lb./sq. in. system from which two turbo-blowers and a turbo-alternator are driven.

Because of its efficiency, it is intended to operate the boiler/turbine unit as a base load set. To maintain it at full output automatic fuel control is provided. This ensures that a supply of fuel oil automatically makes up any deficiency in the normal supply of blast furnace gas. When it is necessary to alter the boiler/turbine load from its optimum setting a manual load setter is operated. This varies simultaneously the feed water and fuel flow to the boiler.

### Increased Demand for Steam and Power

The decision to install the Benson boiler at Margam

resulted from the fact that the proposed "M" Scheme extensions planned for the company's blast furnaces, coke ovens and steelmaking plant within the Margam and Abbey Works would create an additional steam demand of approximately 200,000 lb./hr., for driving turbo-blowers for the furnaces, for generating electricity, and for processing.

The existing plant consisted of two power stations both generating steam at 625 lb./sq. in. and 820° F., interlocked by a 620 lb./sq. in. steam main. The "A" station included: five water tube boilers rated at 100,000 lb./hr., 625 lb./sq. in. and 820° F., fired by blast furnace gas or fuel oil. The steam raised fed four turbo-alternators—two of which were back pressure, the others condensing—and three back pressure centrifugal turbo-blowers. The "B" station included: one 200,000 lb./hr. water tube boiler steaming at 625 lb./sq. in. and 820° F., feeding one pass-out condensing turbo-alternator and one condensing axial flow turbo-blower. There was room for an additional boiler, an additional blower and another turbo-alternator.

Two schemes for extending the plant were considered. One was to install a straight 200,000 lb./hr. water tube boiler steaming at 625 lb./sq. in., similar to the existing boiler, and an axial flow condensing turbo-blower. The other proposal was to include a "topping" installation comprising a Benson boiler and a back pressure turbo-alternator. After very careful consideration the latter scheme was adopted.

### Topping Installation Scheme

Of the many considerations involved in the selection of the topping installation, reference may be made here to some of the more important ones. The total electrical generation capacity in the existing plant was approximately 30 MW.—only about half the normal demand and about one third of the maximum demand. The installation of a critical pressure boiler and back pressure turbo-alternator would make possible the production of 9.5 MW. of electrical generation for works use, thus achieving considerable saving.

A study of the thermodynamics after consultation

with boiler and turbine designers showed that 3,300 lb./sq. in. and 1,060° F. was about the optimum operating condition when considering a total steam flow of 240,000 lb./hr. Above 3,300 lb./sq. in. the main turbine efficiency at the particular flow started to drop, in addition to which the power required for feed pumping became out of proportion to the total power generated. A temperature of 1,060° F. appeared to be a reasonable one at which to operate with a view to avoiding some of the metallurgical problems associated with running at above 1,100° F. and up to 1,200° F., although the gain in electrical output would have been considerable when steaming at 1,200° F.

A complete cost comparison was made between the topping installation operating at 3,300 lb./sq. in. and 1,060° F. and the normal installation at 625 lb./sq. in. and 820° F. The result of this comparison, together with a comprehensive survey including visits to topping installations on the continent, led to the decision that the topping installation would be an economical and practical proposition.

A factor which assisted in reaching the decision to adopt a topping installation was that a number of the existing leading hands, boiler operators and turbine drivers were trained to a very high technical standard.

#### Description of the Boiler

The Benson boiler is a water tube forced circulation boiler in which the feed water is heated, evaporated and superheated in a single passage through a number of tubes in parallel. For generating steam at high pressures, whether above or below the critical pressure, it has many

advantages over boilers using natural or assisted circulation, and the higher the steam pressure the more pronounced the advantages. Benson boilers can be designed and built for operation at pressures up to the order of 5,000 lb./sq. in. and with steaming capacities suitable for any purpose from small industrial plants to the largest central power stations.

The boiler which is now in operation at the Margam "B" power station is the first Benson boiler in Great Britain. The steam conditions are as follows:—

Steam pressure at superheater outlet	3,300 lb./sq. in. gauge.
Steam temperature at superheater outlet	1,060° F.
Feed water temperature at economiser inlet	280° F.
Continuous maximum rating	240,000 lb./hr.
Quantity of steam to the reheater	205,000 lb./hr.
Steam pressure at reheater inlet	650 lb./sq. in. gauge.
Steam temperature at reheater inlet	675° F.
Steam pressure at reheater outlet	628 lb./sq. in. gauge.
Steam temperature at reheater outlet	836° F.

The gross calorific values of the fuels are as follows:

Blast furnace gas	92 B.T.U./cu. ft. at 32° F. and 30 in. Hg.
Fuel oil	18,000 B.T.U./lb.

The output of the boiler can be obtained when burning either of these fuels or a mixture of both.

The disposition of heating surfaces depends on the design pressure and temperature of the unit. The boiler at Margam is arranged with four passes, each directly behind the other. The first pass comprises the combustion zone, the four walls of which form the radiant superheater. Above this is the first evaporator section, followed by the final convection superheater in two sections. Above the superheater is a further evaporator surface in three sections. In this latter surface is the transition zone where the change of state from water to steam takes place. The connecting tubes between the two sections of the final convection superheater are crossed, as also are the connection tubes between the second and third sections of the evaporator sections.

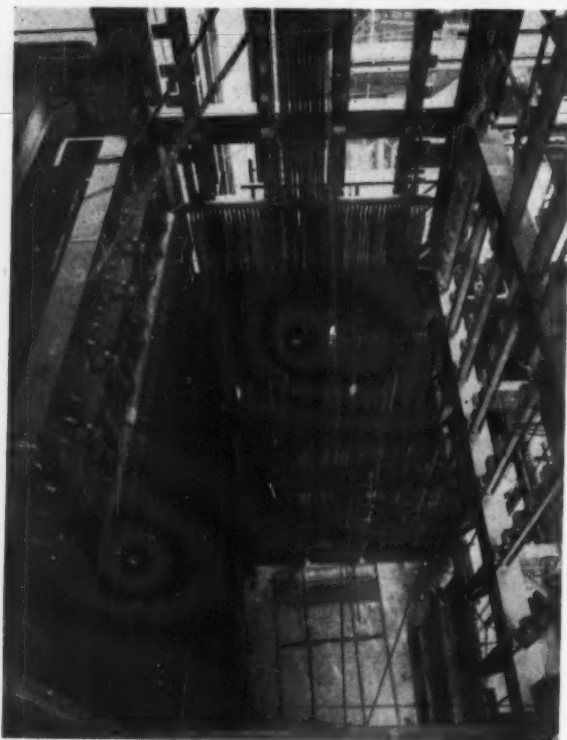
The second pass comprises the reheater sections, arranged in parallel, each section comprising two banks of tubes, and the third includes the secondary economiser sections arranged in parallel, each section comprising three banks of tubes. The fourth or rear pass comprises the secondary tubular type air heater; the primary economiser sections are arranged in parallel, each section comprising four double-flow banks of tubes, followed by the primary tubular type air heater.

The total resistance of the boiler and superheater circuit is overcome by the feed pump delivery head, and this governs the final steam pressure. The variation in this delivery head, by the feed throttle valve, gives the facility to operate at less than the design pressure, which is an advantage in starting-up the main turbine from either cold or hot.

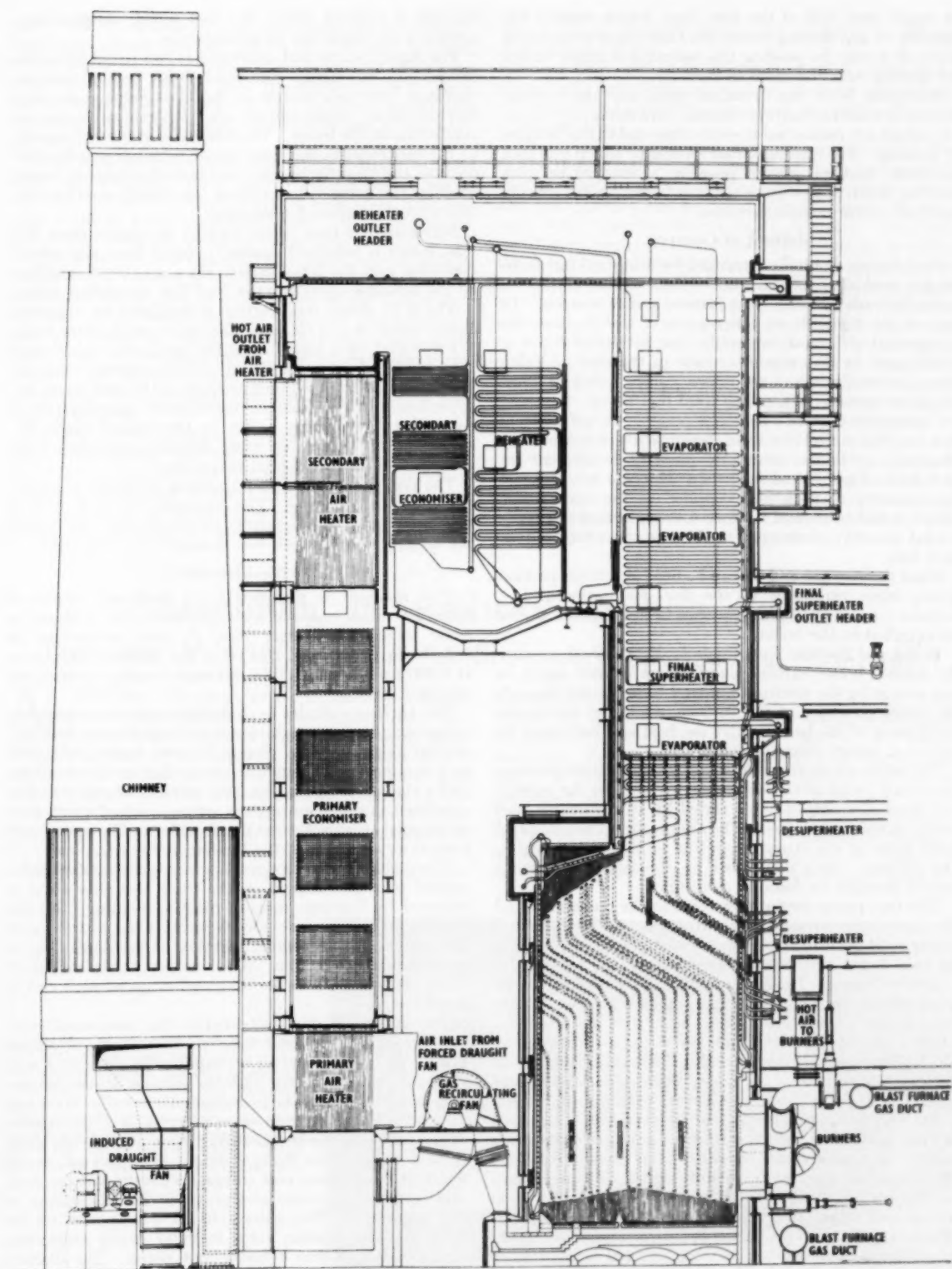
The firing rate is automatically matched to the rate of feed flow, and therefore the final steam temperature is governed by the firing rate with a trimming control from spray type de-superheaters, which form part of the boiler circuit. In this way, also by varying the firing rate, the steam to the turbine can be at less than design temperature, which is a further advantage in running-up the turbine.

A gas recirculation fan is provided to obtain a balance between the superheater temperature and the reheater steam temperature when burning oil fuel.

The reheater temperature is controlled by dampers in



The radiant superheater during erection



Cross section of the Benson boiler at Margam

the upper rear wall of the first pass, which control the quantity of gas flowing firstly over the upper evaporator banks or partly by-passing the evaporator upper banks and flowing over the reheater banks.

The boiler is of the drumless type, and the heating surfaces consist exclusively of small bore tubes ( $1\frac{1}{4}$ — $1\frac{1}{2}$  in. o.d.) which are connected to each other and to the headers by welding. The unit has great flexibility as regards load variation, and so makes possible a starting-up and shutting-down procedure which can be very satisfactorily marched to the turbo-alternator.

#### Method of Control

**Fuel Supply Control**—Arranged for firing by blast furnace gas, fuel oil or any mixture of the two, the boiler will normally burn as much blast furnace gas as possible. In case of gas demands on other parts of the plant or the unexpected reduction in supply, the total fuel input is maintained by automatic increase in the fuel oil firing rate, a precaution which requires a "pilot" fuel oil flame of approximately 10% of the total fuel burnt.

**Combustion Control**—It is not possible to use a steam flow/air flow control for the determination of combustion efficiency, as the stoichiometric quantity is different for each fuel. The method adopted at Margam is to measure the quantity of each fuel supplied to the combustion chamber and to control the forced draught fans to supply a total quantity of air equal to the sum of air required for each fuel.

Blast furnace gas and oil can be fired in any proportion giving wide variations in the flue gas optimum  $\text{CO}_2$  content; an oxygen meter is used as a reference to the air supplied to the boiler.

**Boiler and Turbine Unit Control**—Established practice for normal boiler/turbine plant which cannot apply in this case is for the alternator output to be varied through the speed governor of the turbine, while the automatic equipment of the boiler varies the feed and fuel input to maintain preset steam pressure.

The turbo-alternator at Margam is arranged for pressure governing (with over-riding speed-governing for safety) and the boiler output being varied by an adjustable load setter on the boiler panel. The alternator is then supplied with more or less steam according to the boiler output, the pressure being controlled by the turbine governor valves through an Askania relay unit.

The feed pump output now controls the boiler load and the final steam temperature is dependent on the fuel/feed water ratio with final and more rapid trimming obtained by two stages of spray de-superheating.

**Boiler Control**—The boiler can be operated fully automatically, as shown later, or auto-manually, in which case the valves, vanes, dampers, etc., are actuated by electric motors but controlled by switches operated by the boiler supervisor at the desk. The supervisor is then in complete control of the boiler, utilising indicators and recorders of boiler conditions located in the control room.

On fully automatic control the boiler output is adjusted by the load setter, which consists of a series of rheostats driven by a pilot motor operated from the control desk. The rheostats send out immediate signals of load changes to the fuel controller, with delayed signals to the feed water and steam temperature (spray water) controller. These signals are proportional to the required boiler conditions. The delay in sending out the latter signals ensures that on a rising load the combustion chamber does not cool too rapidly and, conversely, on falling load

the fuel is reduced before the feed water, safeguarding against a too rapid rise in temperature.

The signal to the fuel controller is compared with the summation of signals obtained from potentiometers operated from flow meters in the blast furnace gas and fuel oil lines. These signals are proportional to actual conditions on the boiler. The difference of the two signals to the controller is the error signal, which is amplified to operate the blast furnace gas and fuel oil actuators, hence altering the firing rate to bring the actual condition in line with the required conditions.

Similarly, for feed water control the signal from the load setter is balanced against a signal from the actual feed flow and the error passed via a magnetic amplifier to the actuator operating the feed flow regulating valve.

The H.P. steam temperature is regulated by injecting spray water in two stages. The valve on the first stage is controlled by a signal from the load setter which has been balanced against a signal of the measured temperature obtained from a thermocouple in the first stage de-superheater. The final de-superheater temperature is controlled by a spray valve in the second stage de-superheater; this valve being directly controlled from a thermocouple in the final steam flow.

The forced draught fans supplying combustion air are controlled as follows. The quantity of each fuel is measured and a total quantity of air equal to the sum of the air required for each fuel is supplied to the boiler.

#### Turbo-Alternator

This machine is designed for a terminal output of 9,250 kW. when supplied with 240,000 lb./hr. of steam at 3,000 lb./sq. in. gauge,  $1050^\circ\text{F}$ . and exhausting at 650 lb./sq. in. gauge,  $670^\circ\text{F}$ . The turbine rotor runs at 9,500 r.p.m., is 6 ft. 6 in. between bearing centres and weighs 1,300 lb.

The turbine cylinder is of double walled construction comprising an inner cylinder and flanged outer cylinder of total weight  $4\frac{1}{2}$  tons. Steam from the boiler is received at a strainer placed on the centre line of the machine under the anchor point, and the strainer is connected to combined stop and emergency valves, each of which is in an integral chest with two nozzle valves. The chests are located at each side of the turbine at the front end.

The turbine rotor carries a single row of impulse blades welded to a disc turned on the rotor and this wheel is followed by fourteen rows of reaction blading. All the reaction blades are machined from solid bar with integral shrouding and are welded together at the shrouding in packets of three or four. The dummy piston carries 39 gland strips and there are 30 gland strips at each end of the rotor.

The inner cylinder is divided at the horizontal joint and the halves are held together by a series of shrink rings. The outer cylinder containing the inner is of conventional flanged design with the exhaust steam connection in the middle of the cylinder bottom half. With this design the exhaust steam sweeps the whole of the outside of the inner cylinder, ensuring that the shrink rings remain tight. The inner cylinder is supported in the outer by four palms cast integral with the bottom half, and eccentric keys are also provided for adjustment of the alignment. The outer cylinder is supported on the front and rear bearing keeps by eight strong supporting straps bolted to the cylinder and keeps. The dummy piston glands in the inner cylinder and the main glands in the outer are made up of segments which are spring

supported to permit limited movement to take place. The main glands are provided with two pockets from which steam at 175 lb./sq. in. gauge and 15 lb./sq. in. gauge is tapped. Steam from the nozzle valves is taken through the outer cylinder to the four cast nozzle segments by means of a piston type connection in the inner cylinder.

Each valve chest comprises one single seated combined stop and emergency valve and two single seated nozzle valves. The axis of each valve is horizontal with the nozzle valves above the stop valve. The two upper nozzle valves supply steam to the nozzles in the top half of the inner cylinder and the two lower valves supply steam to the nozzles in the lower half. The chests are interconnected so that on-load testing of the valves may be done. The steam pipes are arranged symmetrically and the chests are supported on linkages which allow expansions to take place freely; the steam joints at the strainer and valves are of a modified Corwell type, comprising a large union nut and nipple with a seal welded packing.

The high steam pressures and the use of single seated valves necessitates the use of H.P. oil to actuate the servo-motors, and this oil is supplied by a pump driven from the front end of the turbine. Lubricating and governing oil is supplied by a conventional gear type pump also driven from the front end of the turbine.

Motor driven auxiliary pumps are provided for starting and emergency use.

Speed and load governing is done by a conventional centrifugal type governor and an Askania regulator is also provided so that the load may be governed by the boiler pressure.

The speed reducing gear comprises an epi-cyclic gear of the double-helical sun and planet type, arranged so that the load is shared equally between the planet wheels and the primary and secondary shafts lie on the same axis, with opposite directions of rotation. The high-speed shaft incorporates a tooth-type coupling, as well as the coupling for bolting to the turbine shaft, whilst the low speed shaft terminates in a solid half-coupling, which is bolted to a similar coupling mounted on the end of the alternator rotor. The gear box bearing at this driving end is enlarged to carry the weight of the this rotor.

The alternator is of the standard turbo-type with direct coupled exciter and is capable of delivering a maximum output of 9,500 kW. continuously when delivering 3-phase electrical energy at the pressure of 10,500/11,500 V., a power factor of 0.7 lagging and a frequency of 50 c./s., when the rotor is running at a speed of 3,000 r.p.m. The construction of the machine is entirely conventional, the ventilator system comprising a fan mounted at each end of the alternator rotor, together with a closed circuit air cooler.

## Aluminium in Railway Rolling Stock

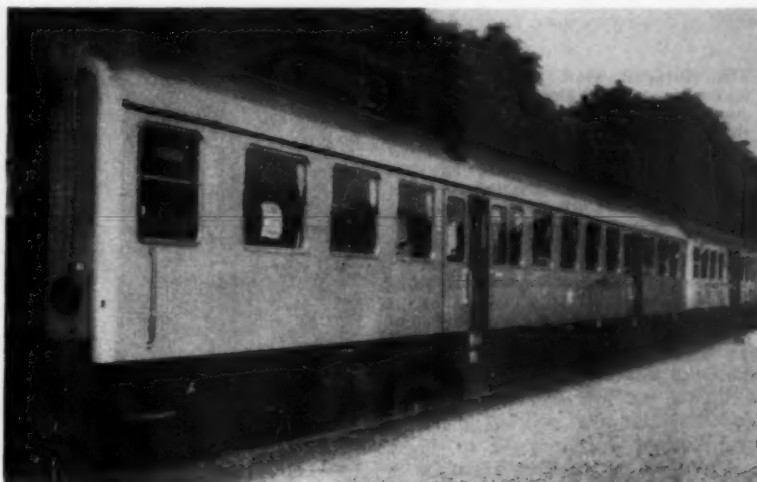
### Forty-five Vehicles on Show at Strasbourg International Exhibition

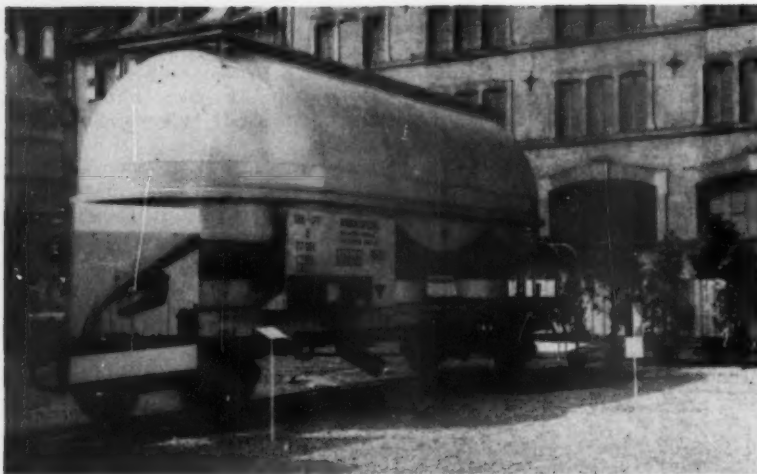
**A**n exhibition of some forty-five railway vehicles incorporating aluminium in their construction was held at Strasbourg from June 21st to June 26th, 1960. The event was organised by the Centre International de Developpement de l'Aluminium (C.I.D.A.), in collaboration with the railway administrations of the countries concerned, with the object of illustrating the established uses of aluminium, and its prospects in this field.

Those attending the opening ceremony from Great

Britain included Mr. D. C. BROWN, president, the Institution of Locomotive Engineers (chief mechanical engineer of the Crown Agents); Mr. G. T. HART, secretary, the Institution of Locomotive Engineers; Mr. J. F. PEPPER, official representative of the British Transport Commission and Mr. A. E. BATES, representing the chief mechanical engineer of London Midland Region of British Railways. The Aluminium Development Association was represented by Mr. W. BRINING, president; Sir Geoffrey Bourne, director-general;

Seating for 86 passengers is provided in this German suburban coach which is of all-aluminium integral construction, inert gas shielded arc welding, spot welding and riveting techniques being used in its assembly. The body has a length of 86 ft. and incorporates 4,870 kg. of Al-Mg-Si alloy. Four prototypes built in 1958-59 are now undergoing trials.





This Swiss silo wagon was built in 1958 and has a useful volume of 1,700 cu. ft., a maximum pay load of 32.7 tons, and a tare of 7.3 tons. The silo and underframe are of Al-4% Zn-Mg alloy—3.8 tons were used—and inert gas shielded arc welding was used in the assembly.

DR. E. G. WEST, technical director; and Mr. F. L. STAFFORD, assistant technical director.

Mr. Stafford, chairman of the Transport Commission of C.I.D.A. was also chairman of the organising body for this exhibition and conference. Strasbourg was chosen as the venue because of its importance as a centre in the European railway network; to this was added the historic interest of the city and the fact that it is an expanding industrial centre.

The exhibits included vehicles with long service experience, new prototypes, and examples of components. The contributions by countries represented were as follows:

*Austria*—A railcar trailer

*Belgium*—A 2-car train set and a passenger carriage.

*France*—A main line coach, two suburban coaches, an articulated coach, an early railcar, a railcar trailer, an open coal wagon, a wagon with automatic discharge gear, a cement wagon, two alumina wagons, a salt wagon, a tank wagon, a sulphur wagon, a wagon with side openings, a wagon with sliding roof and a wagon with trailer.

*Germany*—A TEE-train restaurant car, two suburban

type cars, two railcars, a goods wagon, a wagon with sliding side doors, a wagon with sliding roof, a platform wagon, an alumina wagon and a refrigerator car.

*Italy*—A couchette passenger car, a coal wagon and a tank wagon.

*Switzerland*—A car for narrow gauge mountain railways, a car with pneumatic tyres, a standard first class coach, a covered wagon, a wagon with opening roof, a platform truck, a wagon for transporting motor cars, and a silo wagon.

*United Kingdom*—A London Transport Underground car, a British Railways 2-car diesel train set, a coal hopper wagon, a mineral wagon and a general purpose container.

The wide variety of components included axle boxes, bogie parts, brake equipment parts, pantographs, windows and doors. Semi-fabricated aluminium products on view included special extrusions, large rolled plates, sheets for decorative and other purposes and decorative sections.

Associated with this exhibition were a number of informal technical discussions on general topics.

This interior view is of a British Railways lightweight diesel railcar in course of construction. The first of these was built in 1954, and it is expected that 550 will have been completed by the end of this year. Of fully integrated construction, 4 tons (excluding trim, window frames, etc.) of sheet and extrusions in Al-Mg-Si-Mn alloy are incorporated, assembly being by riveting. Extensive use is made of special mating extrusions in the body structure. The body has a length of 58 ft. and the tare weights of motor and trailer cars are 29 tons and 21 tons, respectively; the corresponding figures for seating capacity are 52 and 65.



This French prototype self discharging coal wagon incorporates about 9 tons of aluminium alloy. The riveted body and underframe are in Al-5% Mg alloy, and the bogie frame in Al-4% Cu-Mg alloy. Castings in Al-5% Cu-Mg-Ti alloy are used in wheel centres, buffers, axle-boxes, centre castings, spring seats, bogie frame, bolster guides, etc. It has a maximum payload of 64.5 tons and a tare of 15.16 tons. Since it was built in 1947 it has run over 200,000 miles, and the behaviour of the sheets in contact with the coal has been excellent.



### Opening Ceremony

The exhibition was opened by PROFESSOR DR. H. OEFTERING, president of the Deutschen Bundesbahn and of the International Union of Railways, who was welcomed by M. ANDRÉ DUMAS, president of C.I.D.A. M. Dumas, after referring to the importance of the exhibition and its significance in connection with railway construction, expressed gratitude to the Société National des Chemins de Fer Français for providing the site and other facilities that made the exhibition possible. Dr. Oeftering referred briefly to the progress of aluminium in its application to railways, and to the evidence of European co-operation in this exhibition, and then performed the opening ceremony by cutting with a pair of anodised aluminium scissors a strip of aluminium tape.

A detailed official tour of the Exhibition then followed, after which the conference delegates adjourned for the inaugural luncheon at which M. Dumas welcomed guests on behalf of the European aluminium industry. In so doing he greeted representatives from the International Union of Railways, from the railway administrations of Germany, Austria, France, Great Britain, Italy, Sweden and Switzerland, from all member companies of the C.I.D.A., as well as from Belgium, Denmark, Spain, Norway, Netherlands, Portugal and Yugoslavia, from the international organisations dealing with the construction of transport vehicles, and finally, representatives of companies which build and use railway rolling stock in Europe. M. Dumas continued (free translation of extract):

"For road vehicles the same tendency which leads to a progressive and inevitable reduction of deadweight achieves it more and more by the use of aluminium alloys, whether for lorries, coaches or touring vehicles. For marine transport there is hardly a ship which has not made use of them to reduce top hamper, with resultant reduction in the engine power and greater stability. The *United States*, the *Oriana*, and (tomorrow) the *France* each have from 1,200 to 2,000 tons of aluminium principally in their superstructures.

"Railway rolling stock cannot escape this development which is characteristic of our time. The first coaches panelled in aluminium appeared on the Liverpool/Southport line in 1905. At this period, however,

the advantages of aluminium had not been fully realised. Constructions of considerable size were not to appear until after the first World War, and then on suburban lines where frequent stopping, necessitating frequent changes of working conditions, make weight reduction extremely valuable. Whilst the use of aluminium in coaches rapidly grew in amount and variety, it still seemed inconceivable that the metal should be used for the construction of wagons—probably on account of its first cost. Among the achievements of the period, three are outstanding: in Germany, the railcar of the Halberstadt/Blankenburg line with its body-structure (1927); in France—the double decker coaches of the Chemins de Fer de l'Etat, where the body-structure is a mixed construction of special steel and duralumin (1930); and in France, again, the articulated train of the Chemins de Fer du Nord, of aluminium-magnesium alloy and arc-welded construction (1933).

"These coaches are still in service, without failure after twenty-five years, and have travelled hundreds of thousands of miles: they represent three characteristic types of construction: three stages which prove the value of the techniques as well as the materials; and three constructions with a record of low weight per passenger carried which has not been surpassed in metal rolling stock construction.

"In goods wagons, competition from road transport opened people's eyes, especially after the second war, to the part which aluminium could play in their construction. Two characteristics in particular have been exploited: resistance to corrosion or to attack from certain products; and the improvement in the ratio of load to tare for transport by complete trains. Aluminium eliminates the use of expensive materials for the fabrication of tanks for nitric acid, hydrogen peroxide and beer; it also reduces the maintenance costs for the transport of coal—for example, the life of aluminium panels has been shown to be three times that of steel panels. The economics are sound, despite the first cost of aluminium, when the saving in weight can be transformed to payload, when the annual mileage is high, or when the characteristics of the line limit the size of the train. Complete trains of all-aluminium wagons have been made up for the regular transport of alumina,

bauxite, coal, sulphur, phosphates, salt, and so on. To be able to benefit from the high ratio of load to tare which is characteristic of these wagons, it has been necessary to obtain from the railway companies an extension, albeit still insufficient, of the tariff regulations.

"Six tons of aluminium are sufficient for the body-structure of a 65-ton payload hopper wagon, thanks to progress in the metallurgy of aluminium and in the technique of using it. Alloys suitable for the requirements of railway structures are principally amongst the non-heat treatable ones, which attain their mechanical properties by cold working have good resistance to corrosion, and are easy to fabricate and weld. They can be supplied in sheets and sections of large dimensions as you have been able to see from many of the exhibits. The extrusion process provides the designer with complex cross-sectional shapes which enable him to realise his designs with the maximum simplicity and speed of fabrication. It is thus possible nowadays to construct a carriage door in a single extruded section.

"Welding techniques have made very great progress, and both spot welding and inert-gas shielded-arc welding are now carried out more quickly on aluminium than on steel. Adhesive bonding, very widely used in aviation, can also be applied to railway construction.

"Many other improvements have now come within reach: the progress which has made possible the flight of the Caravelle today foreshadows that of the railway construction of tomorrow.

"The uses of aluminium today are so varied that its applications in railways is not limited to the actual structure of the rolling stock. It can be used to advantage for fittings in the form of panels or decorative components, polished and anodised. It is a good conductor of electricity, and is used for busbars or cables in electric locomotives, and for conductor rails and overhead lines. A good conductor of heat, it is used for the construction of heat exchangers which thus become lighter and less cumbersome than those in ferrous metals. Its high reflectivity—particularly that of the very pure metal—is used for the construction of untarnishable reflectors for lighting and signalling. In the form of foil, it provides a very light weight thermal-insulating material which does not deteriorate.

"In helping the railways to continue with this task, our metal—and the organisation of which I am president—will be proud to have contributed to the progress of our civilisation. Strasbourg, a city steeped in history, could not have been a better choice for our meeting."

Dr. Oeftering, the principal guest, thanked the C.I.D.A. organisation on behalf of all the railway authorities of the International Union of Railways for the privilege of being able to take an active part in the exhibition which made known the technical accomplishments of C.I.D.A. The fact that railways had been chosen as the subject of this exhibition of the use of aluminium confirmed that the railways still played their outstanding rôle as a means of transport, and showed also that the railways were co-operating with the aluminium industries to further technical progress and in the direction of maximum industrial efficiency. The exhibition was a superb testimonial of European engineering knowledge. Under modern traffic conditions it was no longer possible to do without aluminium: all railway authorities needed its many advantages. Dr. Oeftering went on to emphasise the importance

attributed by railways to low specific gravity of rolling stock and to the fact that the building of lighter vehicles was made possible by modern methods of construction, by the use of resistant materials and of materials of low specific weight. He concluded by referring again to the importance of international co-operation, which he said, had been advocated by the European railways during the one hundred years of their existence. Railways also regarded it as their function to assist all organisations which were trying to advance the technical development of railways on an international scale. It was his particular wish that the Strasbourg exhibition should strengthen the already strong mutual respect between the railway organisations and C.I.D.A. and lead to increasingly effective co-operation.

### Automatic Control of Arc Furnaces

THE Steel, Peech and Tozer branch of the United Steel Cos., Ltd., is installing a BISRA automatic power input controller ("APIC") on their 5-ton electric arc furnace.

In an electric arc furnace, the temperature of the roof refractories is a good guide to the efficient use of electrical power, because unduly high temperatures indicate that power is being wasted. A furnace operates at optimum efficiency when the furnace voltage is regulated to suit each stage of the steelmaking process and condition of the charge. BISRA investigations have specified these voltages for particular furnaces and have shown that the change of voltage can be made automatically so that the optimum voltage is used at each stage.

APIC works the furnace according to a controlled programme of time and roof temperatures. The equipment consists primarily of a synchronous electric timer and devices which continuously measure the temperature, and rate of temperature change, of the roof refractories. When the information relayed by these instruments indicates that a particular stage of melting has been reached, the controller selects the appropriate voltage for the next stage of the programme.

Steel, Peech and Tozer have used the prototype APIC on a continuously operated 5-ton arc furnace. A three weeks trial under observed technical control, followed by a further two months trial under normal operating conditions, has shown reduced electricity consumption and improved melting rate, and some indication of a reduction in roof wear. The company is now building an APIC for permanent use so that the prototype can be released for trials at other works. APIC, by providing a method of automatically maintaining efficient furnace operation, should contribute materially towards improving the economics of the electric arc process.

### Rhodesia May Roll Copper

RHODESIA may set up a copper-rolling mill because of the high cost of sheeting imported from the U.K. From its local head office in Salisbury, Barclays Bank D.C.O. reports that it has been suggested that the mill should be on the Copperbelt. The idea was highlighted recently, adds the Bank, when it was revealed that quality sheeting required in Northern Rhodesia cost £414 per ton delivered in Kitwe from Britain. When the relative order was placed the price of copper was £230 per ton on the London market.

# British Steel Castings Research Association

## Open Days at Sheffield Research Station



The experimental foundry which has been extended in length by 45 ft. during the past year.

**S**INCE the British Steel Castings Research Association built and equipped its laboratories in East Bank Road, Sheffield, in 1956 the staff has increased from twenty-four to seventy-two, of whom forty-five are directly engaged on research, nineteen being graduate investigators. The current annual expenditure is around £100,000, the industrial income being mainly provided by fifty-eight steel foundries in the U.K., who subscribe at the average rate of almost £1,000 p.a., or over 0.16% of turnover: this is twice the national average rate of contribution to research associations. Additionally, financial support is obtained from some steel founders in the Commonwealth, and from a number of foundry equipment and supply companies who are Associate Members and Contributors.

The laboratories, which with the extensions made in 1959-60 have cost almost £200,000 to build and equip, comprise a foundry which provides facilities for pilot plant scale experimentation in steelmaking and all foundry processes; together with a number of smaller laboratories for sands, mechanical testing, radio-isotope work, chemistry, metallurgy, gases-in-steel analysis, and atmospheric dust and fume investigations. A machine shop serves the laboratories by building experimental equipment and preparing test pieces.

In presenting the Association's Annual Report at the Annual General Meeting, the Chairman, Dr. R. Hunter, referred to the conference in January on the subject of atmospheric pollution from steel foundry melting furnaces, which drew from the Alkali Inspectorate a statement of policy. During the past year, the Association has amassed a considerable volume of data on fume emission from melting furnaces and on means for its control: this will form the basis of technical argument to be presented to the Alkali Inspectorate which, if accepted, will result in standards of fume emission more acceptable to the industry, and in less total atmospheric pollution.

Dr. Hunter also referred to two new major activities which have been started during the year, namely the

Steel Castings Development Committee and the special assistance to industry scheme. The Committee has been set up jointly with the British Steel Founders' Association to provide and disseminate data designed to promote the greater use of steel castings. A useful start has been made in the provision of lectures and lecture material for presentation to engineering societies and engineering departments of technical colleges, and substantial progress has been made with a programme of work to determine properties of steel castings on which data are now lacking.

The special assistance to industry scheme has been launched, with special financial assistance from the D.S.I.R., to promote the application of research results in practice. Personal visits will be paid to member firms by senior research staff, either in connection with a single topic—such as oxygen injection in steelmaking, or to discuss the Association's activities in more general terms. The number of requests received in response to an offer to undertake for members work simplification studies in fettling shops and core shops has proved overwhelming, but a start has been made and progress will be maintained as rapidly as possible. Preliminary consideration has been given to the holding of a conference on this subject later in the year, when it will be possible for the Association to indicate by practical examples some of the benefits to be derived from the use of work simplification techniques.

Following the Annual General Meeting, and on the succeeding two days, the laboratories were open for inspection and members were able to see at first hand some of the work described in the Annual Report, and to discuss with members of the research staff those items of particular interest to them. Progress in some of the metallurgical and steelmaking projects have been handicapped in the past by the lack of facilities for the determination of oxygen, nitrogen and hydrogen in steels. Member firms have generously assisted in this respect, but a start has now been made on the establishment of a gas analysis section, and this is expected to become fully

operative during the coming year. Some of the metallurgical projects—particularly that concerned with the effects of inclusions in cast steel—will also benefit from the recent installation of a 56-lb. vacuum melting furnace.

### Steelmaking

The use of oxygen injection for carbon removal during steelmaking has led to the preparation of control charts giving the amount required to produce a predetermined carbon reduction at various bath temperatures. The validity of these charts has been substantiated by further foundry trials and a study has been made of instruments available for metering the oxygen. Experiments to determine the effect of increased agitation due to the ballast nitrogen when air/oxygen mixtures are used for injection, showed that the efficiency of carbon removal was only enhanced when the content before injection was below 0.2%. Fume emission is a feature of oxygen injection and it has been shown that for a given mean carbon level (average of initial and final contents) the fume produced increases with the oxygen flow rate, and for a fixed flow rate it increases with the mean carbon level.

Earlier work had shown that phosphorus could be removed effectively during oxygen injection at low temperatures under a highly basic slag, but there was a considerable reversion of phosphorus to the steel during the subsequent period under a reducing slag for sulphur removal. Experiments have continued using double oxidising slag techniques, the first such slag being removed prior to oxygen injection under a second oxidising slag. Reversion of phosphorus has, however, still been troublesome during the reducing period.

Work has continued on the "reversed slag" process for desulphurisation, in which the steel is melted under a reducing slag and the bath rabbled by a stream of nitrogen. The reducing slag is then removed and replaced by an oxidising slag, oxygen injected to remove carbon, the oxidising slag removed and the heat finished as quickly as possible under a thin protecting reducing slag cover. Gas estimations have shown that there is no significant increase in the nitrogen content of the steel, and that the hydrogen content drops both during the nitrogen injection period and during subsequent oxygen injection, so that the hydrogen content of the cast steel is lower than that of steel of a similar sulphur content made by

the conventional two slag process. In works trials, trouble was experienced with sulphur reversion during and after the oxidising period. This is thought to have been due to pick-up from the hearth which was of dolomite, as compared with the magnesite hearth of the research furnace. Experiments are also in hand to increase the efficiency of sulphur removal by the injection of powdered materials with a high affinity for sulphur with the nitrogen stream. The possibility of entraining lime powder with the oxygen injected for phosphorus removal is also under investigation.

As a first step in a study of the causes of pinhole porosity a test casting has been developed which can be made free from pinholes when desired, and work is proceeding to ascertain the effect of steelmaking, moulding and atmospheric variables.

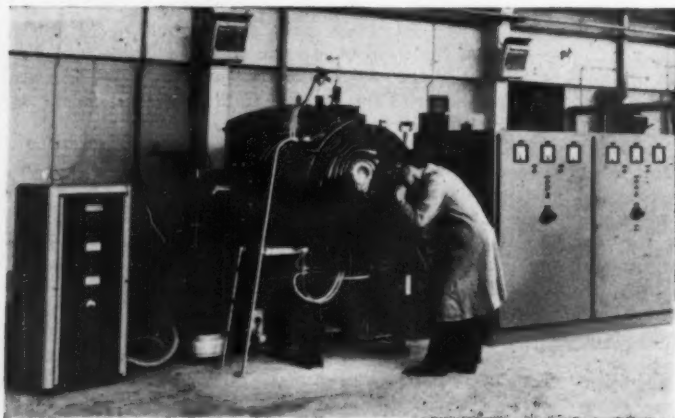
### Moulding

Considerable progress has been made in the work on mould paints and washes, which is mainly concerned with factors affecting the cracking propensity of paints both on drying and under the influence of thermal shock heating. Cracking during drying has been shown to be affected by a number of factors other than the presence of clay in the wash, viz., sand ramming density, sand dry strength, excess suspending agent, the incorporation of very fine powders as a filler, and the addition of inorganic bonding agents. Replacement of the bentonite suspending agent by sodium alginate has been shown to minimise this defect to a considerable extent. Paints using sodium alginate were also better from a thermal cracking point of view.

Trials with a specially developed casting have shown that metal penetration under high ferrostatic pressures can be eliminated provided a thick thermally stable refractory layer of zircon, silica, alumina, or magnesia lies between the molten steel and the sand. This casting has also been used to study the actual mechanism of metal penetration.

The room temperature properties of inflammable type mould washes have also received some attention, and it is now possible to formulate inflammable washes with adequate suspension properties which give good, hard, crack-free surfaces on drying.

The erosion of moulds by molten steel has been shown to be related to the density of the sand compact and the type of bentonite used: cereal additions have been found



The 56 lb. capacity vacuum electric induction furnace recently installed by G.E.C.-Vlavec.

to be beneficial. As the surface roughness of the casting has not provided a reliable measure of erosion, the test casting has been modified and increase in weight is the criterion. In a promising complementary test, a sand specimen is oscillated in rotation while immersed in molten steel.

Friability tests on air drying green sand moulding mixes have resulted in quantitative correlations being established between friability and such factors as moisture content, bonding clay additions, degree of ramming, wetting agents and other additions, and surface sprays, and attempts are being made to correlate it with factors such as speed of drying, etc.

Work on the  $\text{CO}_2$  process has been concerned with hot tearing, and it has been shown that the tendency towards it is no greater than with normal clay-bonded dry sand mixes. The addition of organic materials does not improve collapsibility at high temperatures, but a small amount of clay added to a straight silicate bonded sand may reduce tearing. Factors found to affect the severity include the intensity of milling, the degree of ramming, and the pouring temperature. A suitable test casting has been devised for assessing the ease of breakdown of  $\text{CO}_2$  sands after casting.

A number of air setting, clay tolerant oil binders for moulds and cores has been examined with regard to clay tolerance, bench life and gas evolution on breakdown: no marked increase in hardening rate could be achieved by gassing with oxygen. Other binders examined include aluminium ortho-phosphate solutions and a special polyacrylamide binder, but there was no confirmation that the latter could replace cereal additions to a sand mix.

Work in the B.S.C.R.A. laboratories on the effects of grain size and grain size distribution on the packing density of a silica sand when compacted under standardised conditions, using particles of  $d$ ,  $0.4d$  and  $0.15d$  diameter, has shown the maximum bulk density to be achieved with 70%  $d$ , 5%  $0.4d$ , and 25%  $0.15d$ . The addition of 3% moisture reduced the density markedly: the effect of clay additions is under investigation. In another aspect of this work, being carried out at Sheffield University, the plastic behaviour of clay/water films is being studied in relation to compaction properties when the clay is mixed with sand. In general the factors of greatest importance are the viscosity of the clay/water film and the type of clay: viscosity may be modified by additions of substances such as sodium carbonate.

### Metallurgy

An investigation of microporosity in steel castings, using a semi-microradiographic technique had shown that high phosphorus content can induce a fine crack-like type of micro-porosity in sections too small for the defect normally to occur. Feeding by means of compressed air risers did not result in a completely sound casting, and in view of the difficulty in ensuring that columnar crystals are not bridged over, the technique is unlikely to find wide application.

The mechanism of the improvements in the properties of cast steels as a result of adding rare earths and complex deoxidants will be investigated in the new vacuum melting furnace. The low temperature impact properties of normalised cast medium carbon steel have been shown to be improved by ladle deoxidation with aluminium and mischmetal and calcium-silico-manganese as compared with corresponding steel deoxidised with aluminium



The high temperature tube furnace shown on the right is capable of operating at temperatures up to  $1,500^\circ\text{C}$ . It is mainly used for diffusion experiments in the study of micro-segregation in cast steels.

alone: there is no effect in hardenability and, therefore, on welding.

Work has continued to determine the possibility of reducing the time taken in foundry heat treatment, and the effect of the time and temperature of the austenitising operation on the properties of medium and low alloy steels is being studied on castings of 1, 3 and 5 in. sections. The laboratory work is being supplemented by a study of the behaviour of commercial heat treatment furnaces in the works of Member firms.

A design of test casting giving columnar growth long enough to permit the machining of test pieces from the columnar zone has been developed. Impact test pieces machined along the major axes of columnar crystals gave results inferior to those on test pieces machined transverse to the major axes. Steels with higher sulphur and phosphorus contents are being tested to see whether the increased segregation markedly affected the results.

An investigation is being conducted in the Metallurgy Department of Sheffield University on intergranular fracture in steel castings. Electron microscopy of intergranular fracture surfaces, using a carbon extraction replica technique, have disclosed aluminium nitride precipitates in  $1\frac{1}{2}\%$  Mn steels, but they were on crystallographic planes extending from the grain boundaries into the grains, and not on the fracture surfaces. Large lamellar precipitates found on the latter have been tentatively identified by electron diffraction as  $\text{MnO}$  or  $\text{MnS}$ . In laboratory tests intergranular fracture was synthesised by using 6 lb./ton of aluminium and calcium cyanamide. Electron diffraction studies suggested that in this case the precipitates were  $\text{FeO}\cdot\text{Al}_2\text{O}_3$ , although the correlation in "d" values was not exact.

In vacuum melted steels, with oxygen reduced to an absolute minimum, a precipitate giving rise to intergranular fracture was produced along prior austenite grain boundaries. This precipitate has not been positively identified, but it is considered to be related to the presence of nitrogen, since steels deoxidised with 6 lb./ton of aluminium melted under a nitrogen atmosphere at low pressure exhibited intergranular fracture, while similar steels melted under argon did not.



Magnetic permeameter used for determining the B-H characteristics of cast steel using ring test specimens.

A review of the available knowledge on micro-segregation in steel castings has been made and a programme of research planned: as a first stage consideration has been given to methods of measuring micro-segregation. The ultimate object of this investigation is the development of casting compositions with superior properties, particularly when heated to high tensile levels.

#### Plant Engineering

The Association has carried out trials of sand reclamation by a dry pneumatic unit and by three wet methods. Normal laboratory tests and casting trials have suggested that a very high degree of cleanness may not be required, and that a certain amount of residual clay may be tolerated. A colorimetric method has been developed for determining the live clay in sands containing both live and dead clay, and work is at present in hand to develop a technique by which the total clay can be accurately determined: the dead clay would then be determinable by difference.

An investigation of the performance of three different moulding machines has yielded information on the effect of the machine variables on the compaction of moulding sand. An investigation has also been made of the effect of squeeze pressures exceeding those available on jolt-squeeze moulding machines, and the results show that in order to obtain very high compaction and mould hardness figures, it is necessary to use a sand mix with exceptionally high green strength containing 10% clay and 3% water.

The results of tests to-date on the cleaning properties, relative life and wear of impeller blades with various shot blasting abrasives indicate that chilled cast iron grit has the fastest cleaning rate, followed by malleable iron grit, steel cut wire pellets and steel shot. The wear on the 0-25% C cast steel testing machine parts was least with steel and greater with malleable iron grit, steel cut wire pellets and chilled iron grit, in that order. The life of steel cut wire pellets was 60 times that of chilled iron grit, 27 times that of malleable iron grit and 4 times that of steel shot. The examination in the testing machine of wear resistant materials indicated that white cast irons of high nickel content were superior to high chromium cast irons, and both were superior to plain

white irons for parts of blast-cleaning equipment. For future work, the machine has been modified to provide more detailed information on the relationship between physical properties of abrasives and their efficiency.

Investigations have been conducted on the emission of fume during oxygen lancing on the 6 cwt. laboratory furnace, and tests are being made of the performance of pilot plant collectors when handling fume. Measurements have been made of fume emission during complete melts in electric furnaces and Tropenas converters installed in production foundries. Total emission was found to be remarkably constant, at 5 lb./ton of steel melted, for electric furnaces making carbon steel by the basic double-slag process, with oxygen injection, over a capacity range from 3 to 80 tons. The total emission from Tropenas converters was of the order of 25 lb./ton. As a possible means of defining an acceptable level of discharge from arc furnaces, experiments are in progress to relate the gravimetric fume loading in gr./cu. ft. with the degree of optical obscuration caused by the emission.

#### Industrial Health

Experimental work at the Research Station has resulted in the development of a fettling bench which provides a highly efficient control of dust generated during the fettling of light castings and, at the same time, leads to a substantial reduction in the noise pressure level. Spencer and Halstead, Ltd., and Newton Collins, Ltd., are to produce benches to this basic design under licence from the Association.

A series of annual experiments is being conducted at Reading University to determine whether there is an aggravated hazard to health resulting from the CO<sub>2</sub>/sodium silicate bonding process for foundry sands.

(continued on page 20)



The properties of various types of shot-blast abrasives can be determined and compared from the test results obtained in this machine.

# Control of Intermetallic Particles in Magnesium Alloys by Filtration

By W. Unsworth,\* A.R.I.C.

*Insoluble intermetallic particles in wrought magnesium alloys can be controlled by a filtration process in which the molten metal is passed in a downward direction through a suitable filter bed maintained below the filtered metal level to prevent oxidation. No. 8 grade chilled iron shot appears to be the most practically satisfactory filter material.*

**I**NSOLUBLE intermetallic particles in wrought magnesium alloys can be deleterious in forging and may adversely affect the fatigue resistance of the alloy. The particles are normally either manganese-rich or zirconium-rich, depending on the type of alloy. Although settling processes can be used for reducing the iron content of magnesium alloys, they do not effectively remove the suspended particles normally encountered in wrought stock, even when used in conjunction with favourable temperature gradients.<sup>†</sup> Centrifuging of melts with peripheral fields up to about 100 g fails to give satisfactory removal, although rich concentrations of settled particles are obtained.<sup>‡</sup>

Work was therefore carried out to discover whether these insoluble particles could be removed by filtration, and if so, whether such a process could be readily adapted to the production of substantially particle-free direct chill cast billet and slab.<sup>§</sup> No experiments were made with the high zinc alloy ZW6 (Mg-6%Zn-Zr), in which zirconium-zinc intermetallic particles can form in addition to the "non-dissolvable" zirconium-rich particles<sup>2</sup> present in all zirconium alloy melts.

## Preliminary Experiments with Alloys Containing Manganese

The preliminary work was carried out on the manganese-containing alloys, Elektron AZM and AZ31<sup>||</sup>, since manganese-rich particles are much larger than the zirconium-rich particles encountered in zirconium-containing alloys, and would probably therefore be more readily removed by filtration.

### Early Laboratory Tests

Initial tests were carried out on a 5-10 lb. scale using the following filter media:

- (i) glass wool,
- (ii) steel wool,
- (iii) crushed graphite ( $\frac{1}{8}$ - $\frac{1}{4}$  in. pieces),
- (iv) crushed coke ( $\frac{1}{8}$ - $\frac{1}{4}$  in. pieces),
- (v) crushed refractory brick ( $\frac{1}{8}$ - $\frac{1}{4}$  in. pieces),
- (vi) steel shot ( $\frac{1}{8}$ - $\frac{1}{4}$  in. diameter),
- (vii) pumice.

The filter medium was placed in a thin-walled filtering

crucible with perforated base, the crucible thoroughly preheated, and the bottom then immersed in a bath of relatively particle-free alloy, before pouring on the metal to be filtered. As filtration proceeded, the filter crucible was raised, care being taken that the lower end of the crucible remained below the surface of the filtered metal so as to prevent oxidation. When the greater part of the metal had passed through the filter, the crucibles were water quenched and the solidified metal removed for examination.

In all cases, microscopic examination showed that little manganese removal had been achieved. This was supported by chemical analysis. With (i) and (ii), the filter medium settled down during filtration causing blocking and reduction in metal flow. Reducing the size of the fragments in (iii), (iv), and (v) resulted in much slower metal flow without appreciably improving the removal of manganese particles. Coating the graphite with molten non-deliquescent flux gave slightly better results. In all tests with crushed brick, some silicon pick-up occurred, whilst with pumice the reaction was vigorous. Steel shot gave slightly better results, the removal of particles in this case being comparable with tests using flux-coated graphite chips.

Further tests were carried out using woven fibre glass cloths.\* These resulted in almost complete removal of particles from AZ31 alloy (Fig. 2), but filtration was very slow. More rapid filtration was obtained using B.S. 30 steel mesh, the extent of particle removal being illustrated radiographically in Fig. 7. From microscopic observation however, the effectiveness of the gauze filter appeared at least partly dependent on the entrapment of oxide skins on which particles could be retained; break-through of particles occurred frequently at points where an oxide film was absent or had parted. That oxide films assist the removal of metallic particles by filtration accords with previous experience.<sup>†</sup>

These experiments suggested that a filtration method based on steel gauzes could effect substantial removal of manganese particles from direct chill cast AZM and AZ31 billets and slabs, but that the results might be somewhat erratic due to variations in the quantity and distribution of oxide films collected on the filter.

### Production Scale Trials

A modified reservoir and launder fitted with a removable filter was constructed (Fig. 1) for production scale trials. Eight 300 lb. AZM D.C. cast billets were poured using a filter of B.S. 30 steel mesh. Slices taken from

\* Metallurgist, Magnesium Elektron, Ltd.

† By applying heat to the top of the melt and cooling the bottom, convection can be largely suppressed, thus facilitating particle sedimentation. In the absence of such a temperature gradient, convection currents may prevent effective settling, especially whilst the melt is held in bottom-fired furnaces.

‡ These particle concentrations proved useful, however, in the study of the insoluble particles themselves (reference 3).

§ For method of casting see reference 1.

|| Nominal compositions: AZM—Mg-6%Al-1%Zn-0.3%Mn; AZ31—Mg-3%Al-1%Zn-0.3%Mn.

\* "Tyglas" cloths supplied by Fothergill and Harvey, Ltd., Manchester.

† See reference 2, Figs. 29-31.

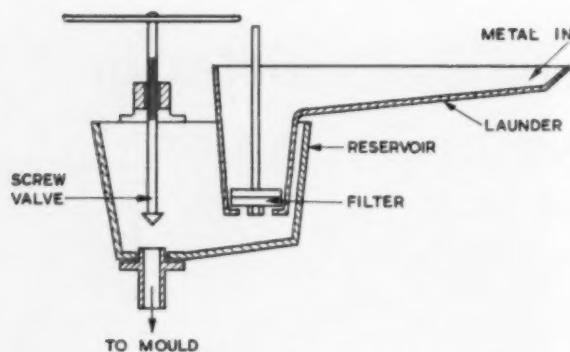


Fig. 1.—Diagrammatic arrangement of filtration apparatus for preliminary production scale trials.

top and bottom of the billets for radiography showed less particles than did those from unfiltered production material.

### Zirconium-containing Alloys

#### Laboratory Experiments

In view of the encouraging results obtained on manganese-containing alloys, 10 lb. scale tests were carried out with stainless steel gauzes of various mesh sizes on Elektron ZW3\* to which a small addition of Elektron AS† alloy (0.5%) had been made, prior to filtering, in order to produce a shower of zirconium-rich particles.‡

With B.S. mesh numbers less than 70, little particle removal was achieved, mesh numbers greater than 80 giving very low rates of metal flow. In the latter cases, some attack on the gauze occurred, especially with the finer apertures (Fig. 3). B.S. 70 and B.S. 80 mesh screens gave some measure of particle removal with reasonable metal flow. Fig. 4 shows the zirconium-rich particles retained by a B.S. 70 screen.

The possibility that several spaced layers of relatively coarse mesh, might be more effective than a single fine mesh was investigated. It was found that as the number of layers of mesh increased, the rate of metal flow fell rapidly, the rate of decrease being greater the greater the mesh number. A double layer of B.S. 30 mesh gave a satisfactory flow rate, but was only slightly more effective than a single layer of B.S. 80 mesh in removing particles. Fig. 5 shows a section through a double layer of B.S. 30 mesh with the particles retained.

The results with spaced gauzes suggested that a loose compact of coarse wire or steel turnings would make a more satisfactory filter bed. Small scale tests showed that compacts made by compressing mild steel turnings (approx.  $\frac{1}{4}$  in. wide and 0.005 in. thick) would give substantial removal of zirconium-rich particles from ZW3. A section taken through such a filter after use and showing the particles retained appears in Fig. 6.

\* Nominal composition : Mg-3%Zn-0.7%Zr.

† Nominal composition : Mg-8%Al-0.5%Zn-0.3%Mn.

‡ Aluminium, like iron, silicon, and certain other elements, is insoluble in magnesium containing dissolved zirconium.

Fig. 2

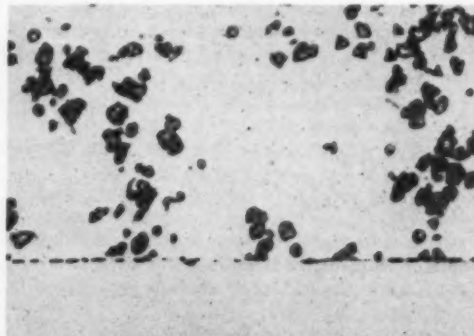


Fig. 4

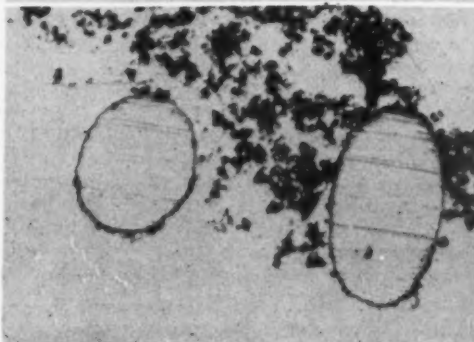


Fig. 3

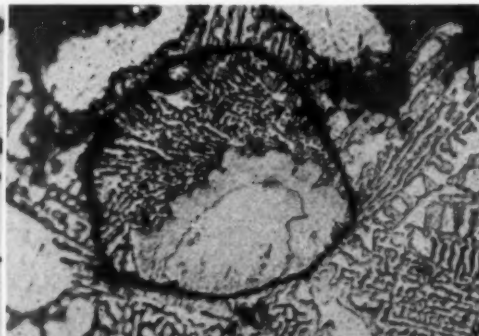


Fig. 5

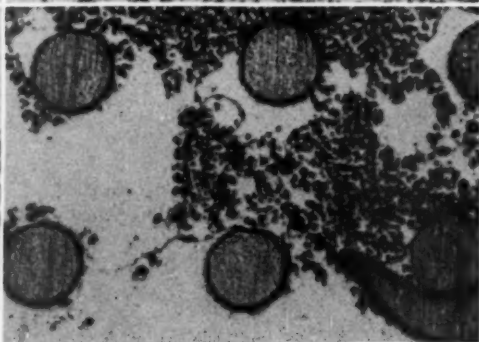


Fig. 2.—Manganese particles in AZ31 retained by glass fibre filter.

Fig. 3.—Attack by magnesium on strand of B.S. 150 mesh stainless steel gauze.

Fig. 4.—Zirconium-rich particles retained by B.S. 70 mesh stainless steel gauze : note the oxide skins present.

Fig. 5.—Zirconium-rich particles retained by a double layer of B.S. 30 mesh steel gauze.

Figs. 2-6.—Sections through filtered melts quenched during course of filtration.

×100

×100

×100

×50

The compacts were made in 3 in. diameter magnesium dies on a small metallurgical mounting press and calibrated\* before use.

To see whether particle removal could be improved by varying the direction of the metal flow, two series of small scale tests were carried out with filters of steel gauze and compressed steel turnings in which the metal was passed in the following directions :—

- (i) upwards through a horizontal filter, and
- (ii) horizontally through a vertical filter.

The results showed that method (ii) gave little or no removal of particles, and the results obtained by method (i) were comparable with those obtained using the downward method; with upward filtration, moreover, the filter was less prone to blockage and the metal flow more uniform.

#### *Production Scale Trials*

Two series of direct chill cast 175 mm. diameter billets in ZW3 alloy were filtered, one series using single and double layers of B.S. 70 mesh steel gauze and the other calibrated steel turnings filters. In all cases the filters were held between mild steel rings and mounted on a threaded rod (Fig. 8). Radiographs taken from top and bottom of the billets showed that billets made using the compressed steel turnings filters were superior to the others as regards freedom from particles, thus confirming the earlier results.

Four 175 mm. D.C. cast ZW3 billets were made using a modified reservoir which enabled the metal to pass in an upward direction through the filter. For these, calibrated rectangular compressed steel turnings filters were used. During filtration, the metal flow lifted the filter from its seating, and on clamping the filter in position metal was forced round the sides of the filter rather than through it. As a result, the billets showed a higher incidence of particles than did those filtered using the downward method. In view of the satisfactory results obtained using the downward method, the upward method was then abandoned.

Although 175 mm. diameter billets could be cast

\* These filters were calibrated in terms of the time taken for 1 litre of mineral oil (viscosity 0.13 c.g.s. units) to pass through the filter under a constant pressure head. Filters of 1 in. thickness with "oil times" of 60-90 seconds were the most suitable.



Fig. 6.—Zirconium-rich particles retained in and above a compressed steel turnings filter: oblique illumination.  $\times 1\frac{1}{2}$

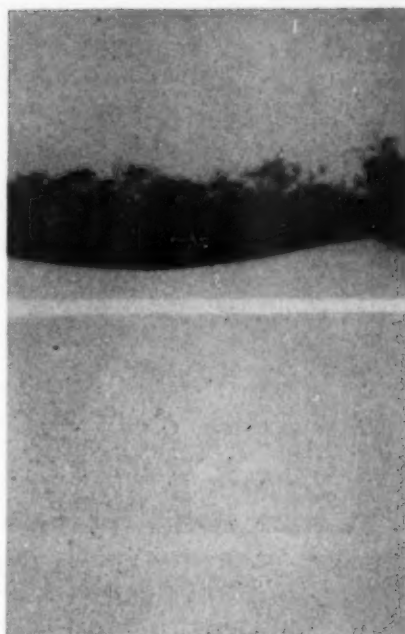


Fig. 7.—Print of radiograph showing the removal of manganese-rich particles using a steel wire gauze of B.S. 30 mesh.

satisfactorily from filtered melts using a 3 in. diameter filter, some blockage with reduced metal flow occurred with larger diameter billets, indicating the necessity



Fig. 8.—Assembly of compressed steel turnings filter used for 300 lb. scale melts.  $\times \frac{1}{2}$

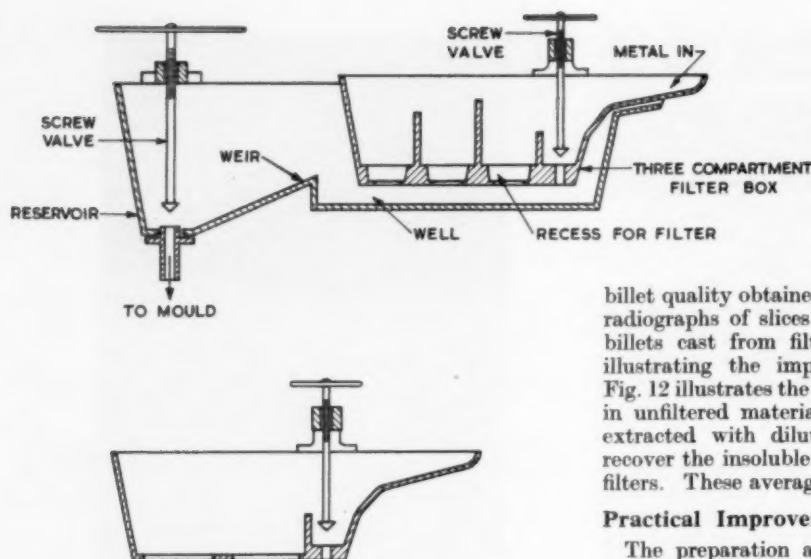


Fig. 9.—Diagrammatic arrangement of reservoir and three compartment filter box used for compressed mild steel turnings filter. The lower diagram is a modified filter box for use with chilled iron shot.

TABLE I.—APPROXIMATE CASTING SPEED FOR D.C. CAST BILLETS AT DIFFERENT RAM SPEEDS.\*

Billet Diameter (mm.)	Casting Speed (lb./min.) with Ram Speeds (in./min.) of					
	2.5	3.0	3.5	4.0	4.5	5.0
175	—	9.75	11.5	13.0	14.75	16.25
220	—	15.0	17.5	20.0	22.5	—
246	15.75	19.0	22.25	25.5	—	—
295	22.5	27.0	31.5	—	—	—

\* The table indicates the minimum rates at which metal must be filtered in casting billets of various diameters.

for a larger filter area. This was in line with calculations of the metal requirements for the various diameter billets at different ram speeds (Table I). To provide the increase in area, a rectangular filter  $6 \times 4$  in. was rammed directly into a tapered container. It was found, as expected, that a better metal flow could be obtained if the filter was placed in a pool of molten metal in the reservoir, and the metal allowed to rise through the filter before filtration was begun. This method, however, gave variable results, even when using filters with the same oil rating. Radiographic examination of several directly rammed filters showed that the packing was not homogeneous. Consequently, a large filter box with three interconnecting compartments each capable of taking a  $3\frac{1}{2}$  in. diameter filter was constructed. This was fitted with a screw valve which enabled the lower compartment to be flooded and the metal forced upwards through the filter before actual filtration was begun (Fig. 9).

Fifty-four 295 mm. and forty-four 175 mm. ZW3 billets were cast from melts filtered by means of the three-compartment filter box and compressed steel turnings filters. Radiographs of slices taken from top and bottom of the billets showed a marked improvement over unfiltered billets as regards freedom from particles (Figs. 10–12).<sup>\*</sup> Figs. 13 and 14 are histograms comparing the percentages of filtered and unfiltered melts in each particle rating group, and show the improvement in

billet quality obtained by filtration. Figs. 10 and 11 are radiographs of slices taken from typical 175 mm. ZW3 billets cast from filtered melts and unfiltered melts illustrating the improvement achieved by filtration. Fig. 12 illustrates the worst quality normally encountered in unfiltered material. Some of the used filters were extracted with dilute hydrochloric acid in order to recover the insoluble zirconium particles retained in the filters. These averaged about 25 g. per 100 lb. of alloy.

### Practical Improvements to Filtration Apparatus

The preparation and calibration of the compressed steel turnings filters proved a time-consuming operation, and an alternative filter medium, more uniform in size and shape and simpler to prepare, was clearly desirable. The requirements of mechanical strength and chemical inertness indicated metallic fragments. Preliminary tests on AZ31 had shown that steel shot of  $\frac{1}{2}$  in. diameter and over was unsuitable, but it was possible that fragments under  $\frac{1}{2}$  in. might be satisfactory.

Eight 295 mm. ZW3 billets were cast from melts filtered using a 1 in. layer of chilled iron shot<sup>\*</sup> supported on perforated steel plate<sup>†</sup> as a filter medium, and were found to approach billets filtered using the compressed steel turnings filters in regard to freedom from particles. The use of chilled iron shot enabled the filter box to be modified, the three interconnecting compartments being replaced by a single rectangular compartment with a filter area of 40 sq. in. A total of forty-four 295 mm. ZW3 billets cast from melts filtered using the rectangular filter box were then found to be satisfactory as regards freedom from particles.

In a further series of melts with differing depths of filter bed, it was found that a depth of  $\frac{3}{4}$ –1 in. was generally satisfactory, and that this could be increased to  $1\frac{1}{2}$  in. without seriously affecting the metal flow. With a depth of over 2 in. the rate of metal flow was markedly reduced and only the smaller diameter billets (up to 220 mm.) could be satisfactorily cast with 40 sq. in. filter area.

### Mechanism of Filtration

The photomicrographs show that the particles retained are much smaller than the pores of the filter medium, and from examination of sections cut through the compressed steel filters, it is evident that the particles are present as loosely settled layers in the filter channels (Fig. 6). This suggests that settlement under conditions of quiescent flow may be involved in the separation of the particles, coupled perhaps with some degree of coagulation brought about by close approach of particles in the narrow channels of the filter.

\* For purposes of comparison the radiographs were assessed visually in arbitrary units, the significance of which is indicated by Figs. 10–12.

\* No. 8 grade supplied by Longhill Foundry, West Hartlepool. For size grading see Table II.

† Mild steel sheet with  $\frac{1}{8}$  in. diameter perforations, supplied by Marsden and Bateson, Birmingham.

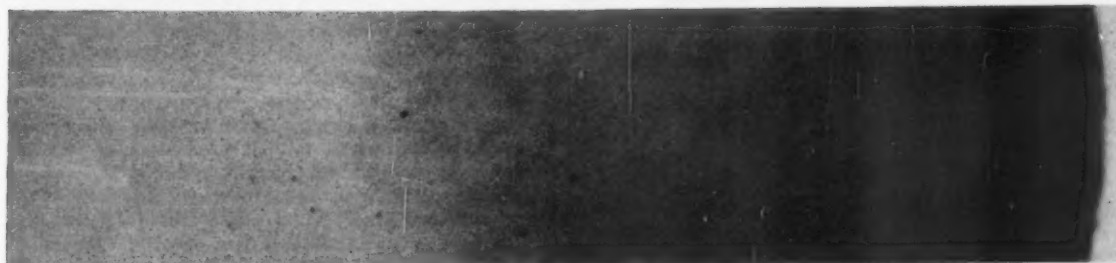
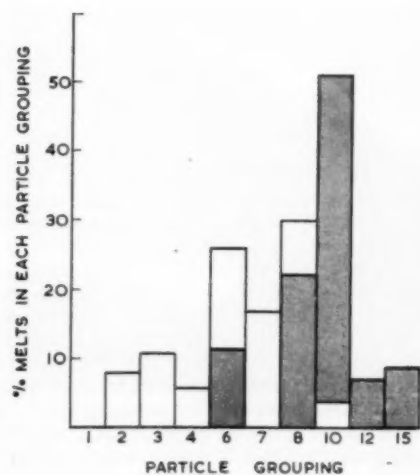


Fig. 10. (top)—Filtered melt (radiographic rating 2).

Fig. 11. (middle)—Typical unfiltered melt (radiographic rating 8).

Fig. 12. (bottom)—Unfiltered melt, representing the worst quality commonly encountered in unfiltered melts. (radiographic rating 12).

Figs. 10-12.—Radiograph prints of 175 mm. diameter billet slices ( $\frac{1}{4}$ -1 in. thick) in ZW3 alloy showing zirconium-rich particles (dark).



Figs. 13 and 14.—Histograms showing distribution of particle ratings for 295 mm. and 175 mm. billets cast from filtered and unfiltered melts. The shaded areas represent unfiltered melts.

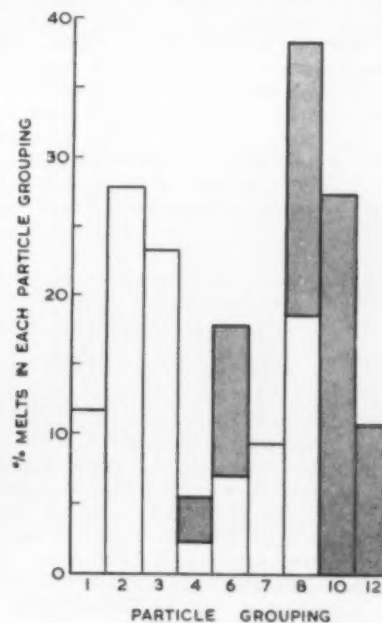


TABLE II.—SIZE GRADING OF NO. 8 CHILLED IRON SHOT.

Particle Diameter (in.)	<0.085	0.085 -0.089	0.090 -0.094	0.095 -0.099	0.100 -0.104	0.105 -0.109	0.110 -0.114	0.115 -0.119	0.120 -0.124	0.124
Fraction (%)	0.8	1.9	7.7	19.6	26.2	18.8	12.3	9.2	2.8	1.2

### Conclusions

The insoluble particles in wrought magnesium alloys of aluminium and zirconium types can be substantially removed by a "filtration" process. This can best be performed by passing the molten metal in a downward direction through a suitable filter bed maintained below the filtered metal level to prevent oxidation. Chilled iron shot  $\frac{1}{16}$ – $\frac{1}{8}$  in. diameter (No. 8 grade) appears the

most practically satisfactory filter material. The size distribution of this grade is given in Table II.

### Acknowledgment

The author's thanks are due to the Directors of Magnesium Elektron, Ltd., for permission to publish this paper.

### REFERENCES

- 1 Wilkinson, R. G., and Hirst, S. B., *J. Inst. Metals*, 1953, **51**, (7), 393.
- 2 Emley, E. F., *J. Inst. Metals*, 1949, **75**, 481.
- 3 Emley, E. F., *Brit. Foundryman*, 1958, **51**, 501.

### New Heavy Oxygen Cutting Rig

A new heavy oxygen cutting rig for mild steel and steel castings up to 5 ft. thick has been developed by British Oxygen Gases, Ltd. It incorporates the company's latest nozzle mixing blowpipe using propane as the fuel gas. Apart from providing industry with a means of cutting greater thicknesses, the new equipment also improves the ease of cutting, safety, and quality of finish. The cutter is particularly suitable for removing risers from castings—the sizes of which are ever increasing—as well as for breaking up large forge hammers, ladle bottoms and other scrap material for re-melting or disposal.

A particular example of the need for such equipment arose when a foundry had to remove two riser heads, each 61 in. thick. The finished casting forms the side member of a rolling mill housing. Although its finished weight is 160 tons, in the "as cast" condition it weighed 225 tons and was too heavy for the foundry's largest crane. The riser heads had to be cut off in the casting pit in a horizontal position and could be cut from one side only, an operation which had not previously been attempted but which, when carried out with the new cutter, took only 50 minutes for each riser.

During 1959 British Oxygen Gases carried out development work at various steelworks in Yorkshire. The steel companies were most helpful in providing facilities for field testing and, with their co-operation, B.O.G. were able to make the trials necessary to prove the new design. A number of these cutting rigs have now been sold, one of the first being installed in the new and imposing foundry of Sulzer Bros. in Switzerland, and enquiries have been received from all parts of the world, including the U.S.S.R. and Japan. British Oxygen Gases' development work continues to increase the depth of cutting still further.

### Large Continuous Caster

THE new four-strand continuous casting plant which Distington Engineering Co., Ltd., are to build and instal at Appleby-Frodingham Steel Co., Scunthorpe, will have the largest productive capacity in the world for a machine of its type. Equipped to cast four strands of 9 in. square blooms, the Distington machine will be designed to operate from 100 ton ladles of steel, with a weekly production capacity of 5,000 tons. It is scheduled to begin operations in December, 1961.

Liquid steel will be poured from the ladle into a

common tundish, with four stopper-controlled nozzles feeding direct into the copper moulds. After leaving the spray cooling chamber, the solidified blooms—withdrawn through pairs of withdrawal rolls—will be cut off vertically into 30 ft. lengths. These will be discharged at ground level by means of a discharge conveyor mechanism. The blooms will then be transferred to a new 32 in. reversing mill for rolling into billets to feed the new Appleby-Frodingham rod/bar mill, which will have a capacity of 300,000 tons per annum of finished products.

Although the continuous casting plant will be the first to be built by Distington, the personnel of the company's continuous casting division have all been closely associated with the pioneering work which United Steel has been carrying out on experimental machines over the past seven years.

### The Polarographic Society

THE Polarographic Society now has a permanent address for mail. Enquiries concerning the Society should be addressed to The Polarographic Society, c/o Lloyds Bank, Ltd., 36, High Street, Wealdstone, Middlesex.

### Steel Castings Research

(Continued from page 14)

Although no final conclusions can yet be drawn, it does not appear that there is any marked difference from ordinary sands.

An assessment, of the collection efficiency of a wet scrubber on electric furnace fumes showed the figure to be no higher than 59% during oxygen lancing, as compared with 75% during melt-down. Similar performance was shown by a pilot plant dry type of collector in which the filtering bed consists of mineral grit.

### Non-Destructive Testing

Work on the ultrasonic examination of steel castings, which is being carried out under contract from the War Office, has been concerned with an assessment of the sensitivity of the method for the detection of internal defects, and the variables studied have included the effects of composition, heat treatment, surface condition, and the frequency of the ultrasonic pulses. A comparison has been made between the sensitivity with normal surface applications of the probes and with immersion in water. The results have been very encouraging and it is thought that there is considerable scope for this method of non-destructive examination in many steel foundries.

# Hot-formed Coil Spring Manufacture\*

By R. Haynes, B.Sc., A.Inst.P., A.I.M.

*The purpose of this article is to survey modern hot-formed coil spring manufacture with reference to both good and bad practice, and to give as a whole, accepted up-to-date production methods.*

## Initial Bar Stock

THE starting point of the spring manufacturing process is the bar stock, and it is most important that material of the correct type and having a satisfactory surface finish should be obtained. Bar as received from the rolling mill is black owing to the existence of a thin adherent film of scale, which may conceal defects such as the flaw which resulted in the fatigue crack shown in Fig. 1, the decarburisation

resulting in the fatigue crack in Fig. 2, and the seam which caused the failure shown in Fig. 3: a normal fatigue failure has the appearance seen in Fig. 4. All the defects referred to here can be removed by grinding, with the possible exception of deep seams, which can, however, be located by crack detection methods. Fig. 5 shows the surface finish of a ground bar (note the scale-free surface).

The concealment of surface defects by the presence of scale results in the re-roller refusing to guarantee black bar against surface defects, although clause 6a in B.S. 24: 3B states that such defects should not be present. Spring makers, therefore, when handling black bar,

\* Paper based on a lecture delivered to the Sheffield Trades Technical Society.  
† Director of Research, Coil Spring Federation Research Organisation.

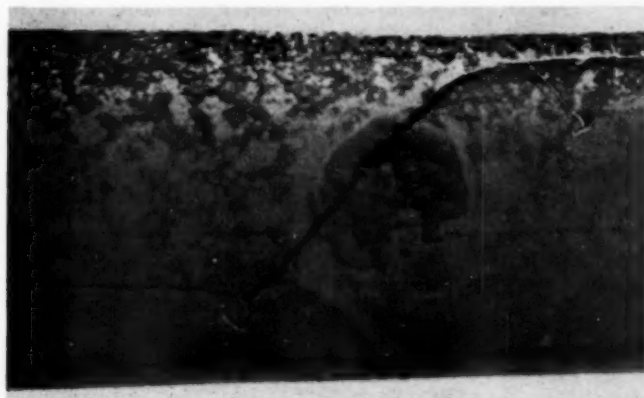


Fig. 1—Flaw concealed by scale resulting in a fatigue crack.

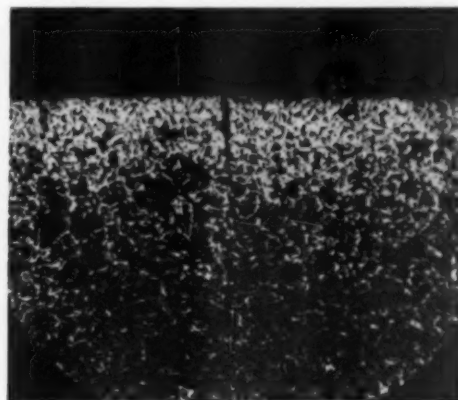


Fig. 2—Fatigue crack originating in a decarburised surface.



Fig. 3—Fatigue failure due to a seam in the original bar stock.

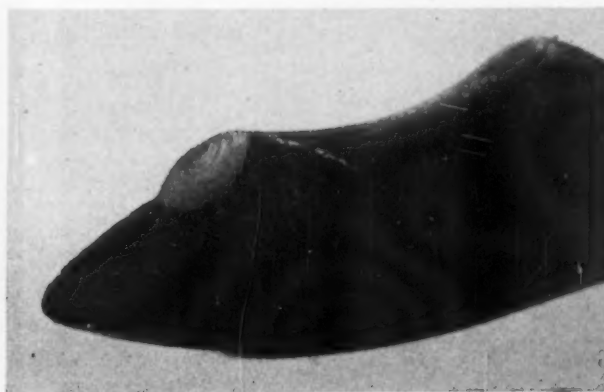


Fig. 4—Normal torsional fatigue failure with the origin of failure clearly discernible.

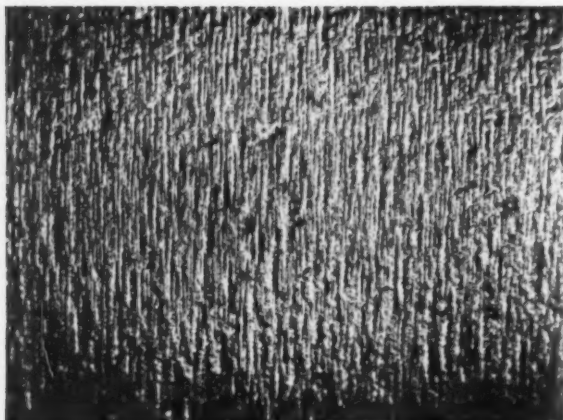


Fig. 5—Surface finish of a ground bar.  $\times 10$

carry the risk of manufacturing springs from faulty material with the faults themselves becoming apparent at some late stage in the manufacturing process, such as pre-stressing, with all the resulting financial loss involved.

Apart from surface finish the actual type of steel selected is important, particularly when the section of the spring bar is large, since the ideal final metallurgical condition is one with a tempered martensitic structure as shown in Fig. 6; note the dark needle-like form of the grains. Failure to harden fully to a reasonable depth will result in an unsatisfactory metallurgical condition such as the pearlitic structure shown in Fig. 7; note the lamellar pattern of carbide and free ferrite, which has a lower elastic limit and less toughness than the tempered martensite. A martensitic structure right to the centre is not essential for reliable performance of a material stressed in torsion, but if the steel can only be partially hardened there is grave risk of failure to harden at all if the quenching conditions are not good, so that a through hardening steel is desirable.

The effect of the hardenability of various steels on the final hardness, and hence the tensile strength, across a section after quenching is shown in Figs. 8—10. The first (Fig. 8) shows the hardenability curves of carbon and

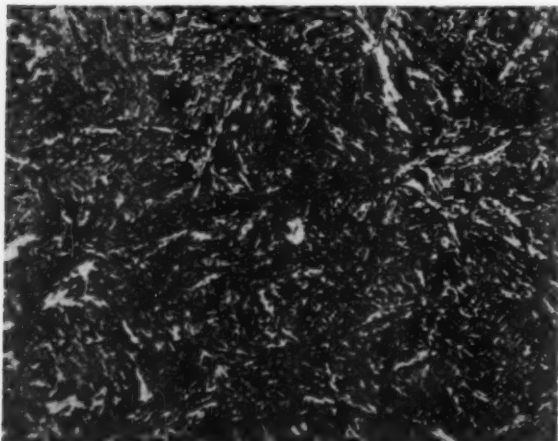


Fig. 6—Tempered martensitic structure.  $\times 500$

TABLE I.—ANALYSIS OF THE FIVE STEELS WHOSE HARDENABILITY CURVES ARE SHOWN IN Figs. 8 and 9.

Steel Type	Cast No.	C%	Si%	Mn%	S%	P%	Ni%	Cr%	Mo%	V%
Ni-Cr-Mo	HJ4182	0.64	0.20	0.87	0.013	0.014	0.69	0.58	0.20	—
Cr-V	HH3067	0.50	0.41	0.65	0.012	0.018	0.18	1.01	0.05	0.18
Carbon	35742	0.98	0.14	0.39	0.039	0.028	0.07	0.05	—	—
Si-Mn	36301	0.57	1.94	0.82	0.012	0.037	0.06	0.08	—	—
Si-Mn(special)	P66673	0.57	1.78	0.87	0.012	0.031	0.20	0.29	0.23	—

chrome-vanadium spring steels compared with a low nickel-chromium-molybdenum steel of the SAE 8660 type. It may be seen that the carbon steel is only satisfactory up to about 1 in. diameter, the chromium-vanadium up to about 1½ in. diameter and the low nickel-chromium-molybdenum up to at least 2 in. diameter. Fig. 9 gives for comparison an ordinary and a special silico-manganese steel. The ordinary silico-manganese is satisfactory up to about 1½ in. diameter, whilst the special silico-manganese is satisfactory up to at least 2 in. diameter: the latter steel contains small additions of chromium and molybdenum. A silicon-chromium steel and SAE 5160 are shown in Fig. 10: as may be seen, these are satisfactory up to 2 in. section. The analyses of the first five steels are given in Table I.

It should be noted that the hardenability characteristics shown have been determined on 6 in. long straight cylinders freely quenched. The results on large closely coiled springs with more restricted quenching would be less attractive, and this would have to be allowed for in practice when selecting the steel.

The Coil Spring Federation Research Organisation is looking further into this matter of hardenability of spring steels, with special reference to influence on fatigue life, to enable Goodman type diagrams to be constructed which will assist the spring designer to design springs which will not fail in service due to fatigue.

#### End Formation

The first process normally carried out by the spring maker is the formation of the end of the bar. This consists of producing a taper at each end so that, when the spring is formed and the end coil brought into contact with its adjacent coil, there will not be a large amount of material to be removed during grinding in order to provide a flat base.

The degree of heating of the end prior to forming is most important. Overheating in its severest form, i.e.

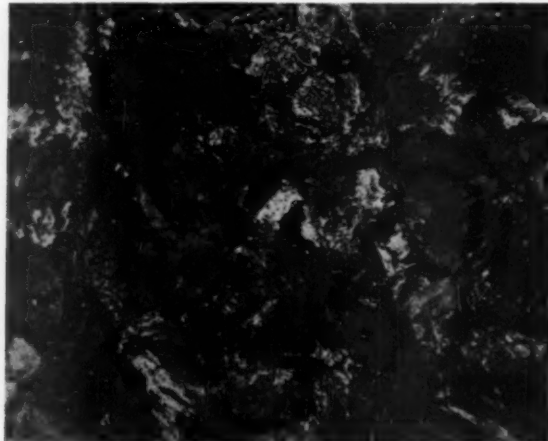


Fig. 7—Pearlitic structure.  $\times 500$

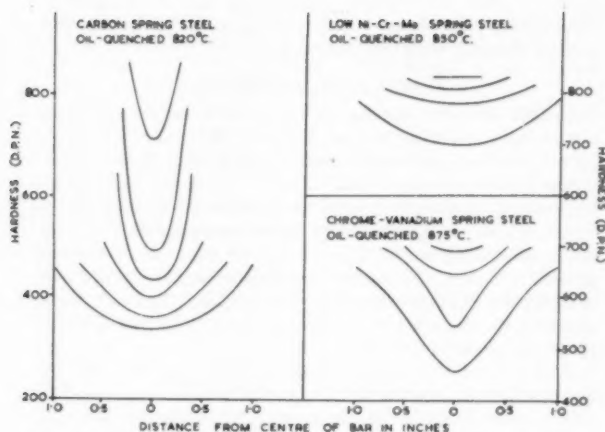


Fig. 8—Hardness traverse curves for bars of carbon, chromium vanadium and low nickel-chromium-molybdenum spring steels.

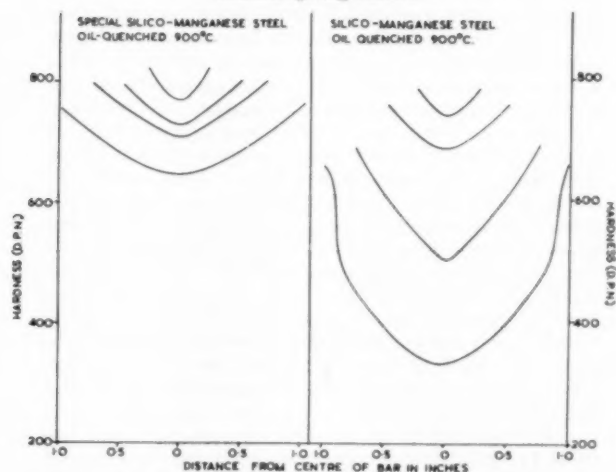


Fig. 9—Hardness traverse curves for bars of ordinary silico-manganese spring steel and a similar steel with small additions of nickel, chromium and molybdenum.

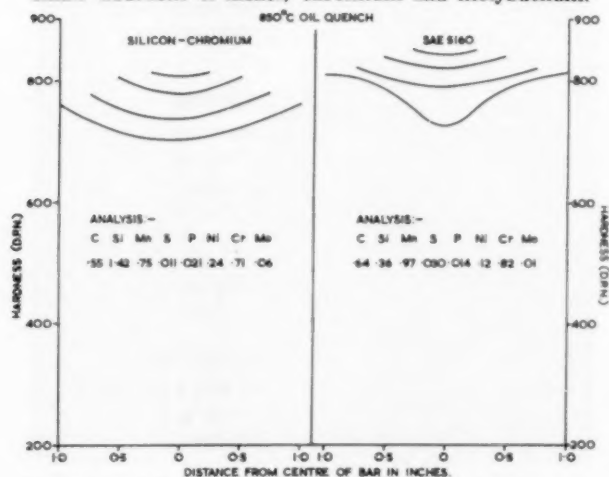


Fig. 10—Hardness traverse curves for a silicon-chromium spring steel compared with SAE 5160.



Fig. 11—Forming a flat on the end of a spring steel bar by rolling.

burning, causes oxide formation at the grain boundaries near the surface, and this can result in breakage of the end coils during the pre-stressing operation.

There are two techniques of forming widely used in the industry, viz: rolling and hammering. Rolling gives a better surface finish in that the taper is gradual, whereas hammering may give a stepped surface in the tapered end. The former process is demonstrated in Fig. 11.

Whatever the method of tapering, it is important that the profile be correct. If the end of the taper is too thick there will be a large step at the end face which will result in an unduly uneven distribution of load bearing surface. If the end is too fine it might result in curling of the end of the spring during later manufacturing stages, or breakage of the end under load.

#### Heating for Forming

The time spent in heating for forming should be kept as short as possible compatible with giving the steel sufficient plasticity to permit coiling to take place. From this point of view it is more important to heat the outer surface layers to render them plastic than the core, it is therefore permissible for the latter to be at a lower temperature. However carefully the furnace atmosphere is controlled the steel will tend to decarburise unless the coiling temperature is kept as low as is practicable.

The bars may be heated by alternative processes such as resistance or induction heating. The drawback to the former process lies in the difficulty in getting the ends of the bars sufficiently hot. Induction heating is attractive in that it heats directly only the outer layers of the bar, which is what matters most for coiling.

Sometimes direct quenching from the mandrel is carried out, in which case the heating conditions outlined above would be inadequate and the procedure outlined below under "Heating for Quenching" should be followed. Springs made from material that requires a high coiling temperature should, after coiling, be cooled through the transformation point and then reheated for quenching without necessarily cooling to room temperature.

#### Forming and Setting-up

During forming on the mandrel, it is important that



Fig. 12—Typical quenching plant for heavy coil springs.

the end points be bedded in to follow the coils of the spring. There may be a temptation to leave these jutting out and remove them later by grinding, thus producing a spear point with the tip of the point lying along the outer circumference of the spring. This causes a loss in bearing surface area and makes it more difficult to obtain a square seating for the spring. It is particularly bad practice when the end points are coincident, i.e. when the spring has a complete number of turns, as can happen when the design is restricted by space limitations.

When laying the end taper of the bar onto its adjacent coil, it is important that the outer flat surface of the taper be in a plane parallel to the sectional axis; if this condition is not obtained, it will be difficult to get a square seating subsequent to the grinding operation; a loss of bearing surface will result with a consequent maldistribution of load.

It is important to bear in mind that during the coiling process and subsequent setting-up heat is continually being lost, and speed of operation is therefore most important. It is not practicable to measure the temperature of each spring, either during forming or after setting-up and prior to quenching, and because of this the actual quenching temperature is never known. A method of overcoming this drawback is to re-heat the spring to the correct quenching temperature and then quench directly from the furnace. However, this results in an extra stage and therefore an extra cost, and is also likely to lead to more decarburisation if the furnace atmosphere is not properly controlled and if scale is present on the spring.

Setting-up is the process of opening a closely wound spring to give a spacing between the coils such that when the spring is finally compressed solid it will finish with the correct free height. Naturally it does not apply to springs formed on grooved mandrels. The selection of spring height at the forming operation in order to give a

correct final free height can only be satisfactorily decided by experience. This is discussed further in the section dealing with prestressing.

### Heating for Quenching

In this case the heating must be sufficient to raise the temperature of the material above its transformation points, and so provide a metallurgical structure appropriate for quenching. At the same time it must not be so high as to cause grain growth. This is one respect in which silico-manganese and chromium-vanadium steels are advantageous, in that they are resistant to grain growth. Likewise, aluminium-killed carbon steels are suitable for springs where the section is not greater than about  $\frac{1}{2}$  in. Alloy steels such as SAE 8660 are usually grain controlled.

It is essential to ensure that enough time be allowed for the spring to achieve the correct temperature, and in this respect both the thermal capacity of the furnace and the mass and distribution of the charge must be taken into account. Once all the material of the spring has attained the correct temperature it is sufficient to allow the spring to remain at this temperature for a few minutes in order that the desired metallurgical changes may take place.

During this phase there is a danger of the surface of the steel becoming decarburised unless the furnace atmosphere is carefully controlled. To exclude oxygen is not enough, since the presence of hydrogen in the form of water vapour may result in carbon removal in the form of methane. A normal gas fired furnace is not as effective as the smoky atmosphere produced by coal or creosote firing, but having consideration for smoke abatement requirements it is better to utilise partially burnt town's gas in an electric furnace, having first cooled the burnt gas to remove the water vapour. Even in the perfect furnace atmosphere decarburisation may still take place if black bar is being treated, since the scale adherent to the steel will tend to remove carbon from the surface layers in the form of carbon monoxide and carbon dioxide.

The behaviour of scale during the double heat treatment process has recently been examined in detail by the Coil Spring Federation Research Organisation, and it has been conclusively demonstrated that the scale formed during the first heating process and during coiling can be sufficient to decarburise the steel partially during the second heat treatment operation, and also to act as a thermal barrier during the quenching process, with the result that the ideal metallurgical structure is not obtained. Furthermore, this inferior structure together with the loss of surface carbon definitely lowers the fatigue life.

### Quenching and Tempering

It is most important that the quenching be adequate. This requires a good quality quenching oil, agitation of the bath, and use of some form of cooling system for the oil. If agitation is not used, the oil will tend to vaporise on the skin of the spring and form a vapour barrier between the hot spring and the cold oil. This in turn will lead to a slack quench and possibly an unsatisfactory metallurgical structure of the steel. Good agitation will either prevent the vapour film from being formed or will remove it as soon as it is formed, so that the spring will maintain contact with the liquid oil and a rapid quench ensue. If a cooling system for the oil is not used, the temperature of the bath will tend to rise during the day

and this may be particularly serious in hot weather when the ambient temperature is high. In no case should the temperature of the oil be allowed to rise above 70° C., except in the case of some alloy steels, when higher temperatures may prove advantageous.

An investigation is being carried out by the Coil Spring Federation Research Organisation into the efficacies of six different quenching oils, and also with certain additives to water which will enable oil quenching conditions to be simulated. These quenching media will be tested with a variety of spring steels.

Sometimes hardening (i.e. quenching) cracks may occur when quenching from the mandrel. This is due to grain growth which occurs more rapidly at the higher temperatures required for this single heat treatment. There may be a temptation to overcome the problem by using a fine grained material such as an aluminium-killed steel. While this is permissible for springs of up to about  $\frac{1}{2}$  in. diameter section, it is to be discouraged for springs of larger section, since the fine grain structure will not have the hardenability desired.

A further method of avoiding quenching cracks is to refrain from continuing the quench until the spring is cold, but to remove it from the oil when its temperature is about 150° C., and then to temper it immediately. Clearly, if this quenching procedure is followed it is no use placing the spring on one side to temper it later, nor to batch temper.

When the spring first enters the oil, it has, by virtue of its high temperature, a very low mechanical strength and it may sag under its own weight. It is therefore important that it be adequately supported prior to and during immersion in the oil. The cradle must therefore perform the dual function of keeping the spring straight, and not conducting too much heat from it, since this would lead to uneven cooling and hence buckling.

Quite often the supporting arrangements in oil quenching tanks contain several cradles although the manufacturing procedure can only supply one spring at a time. This may necessitate lifting a partially loaded rack clear of the oil, placing upon it a hot spring and lowering the assembly once more into the oil. There is



Fig. 13—Grinding the end coils of a heavy coil spring.

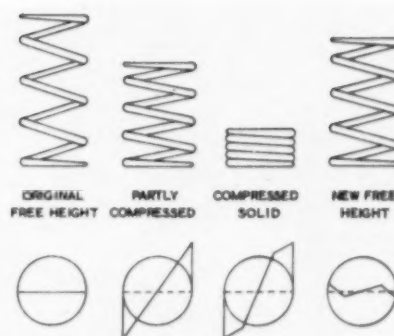


Fig. 14—Demonstration of the effect of pre-stressing on the stress distribution in the material of the spring.

a risk that a spring on the rack may not be completely cooled prior to its temporary removal from the oil, i.e. it may still have a hot core which will tend to raise the surface temperature again and give a softened metallurgical structure. A typical quenching plant is shown in Fig. 12.

Tempering is carried out to eliminate the quenching stresses and increase the toughness by allowing certain structural changes to take place within the steel. It is undertaken by heating the spring in the region of 400–500° C., according to the type of steel, for a period of 15–20 minutes after the tempering temperature has been attained. It is important in this respect that both the capacity of the furnace and the size and distribution of its charge be allowed for. It may be seen from this that springs of small section should not be placed on the same tempering trays as those of large section since they will require different periods of time to attain the tempering temperature. At all costs the overloading of furnaces should be avoided, since some parts of the charge will then take longer to get to the correct temperature than others. This is of particular importance in the case of chrome-vanadium steel owing to its time-temperature tempering characteristic.

### Grinding

A great deal could be said on this subject if one took into consideration the many types of grinding machines, wheel materials, peripheral speeds, and so on, but perhaps the main thing to emphasise is that care must be taken not to overheat the ends of the spring during the grinding operation, since grinding cracks are likely to occur due to the sudden heating and cooling of the end coil. This may prove to be more troublesome when piece rates are being worked and the machine operator is, naturally enough, interested in very high throughputs. Fig. 13 shows a heavy spring being ground.

### Pre-stressing

Compression treatment is necessary in order to pre-stress the steel. The effect is to strain the material in shear until the outer layers are moved beyond their elastic limit and plastic strain takes place. The core is not so highly stressed, however, and the strain in this instance remains below the elastic limit. When the spring is released it returns partially to its original position by virtue of the elastic properties of the core, but is prevented from doing so fully owing to the plastic deformation that has taken place in the outer fibres. The net result is a stress



Fig. 15—Equipment for the pre-stressing of heavy coil springs on a production basis.

distribution of the kind shown in Fig. 14; the important thing to note is that the torsional stress in the surface layers has been reversed. This has the advantage that it increases the apparent elastic limit of the material of the spring and at the same time prevents it from settling down in service if the structure and design are correct. Fig. 15 shows road vehicle suspension springs being pre-stressed.

Owing to the plastic deformation which takes place during the compression operation there is a loss in free height. This means that the spring designer must take the treatment into account when designing the set-up height at the forming stage. There is no fundamental way of calculating this and as a result it is computed from empirical data. Fig. 16 shows two such curves for carbon and silico-manganese steel which have been compiled from experimental results. It can be seen that it is possible for any desired final stress to be read-off in terms of a set-up stress. It is important to note further that the curves are different for carbon and silico-manganese steels, and will probably be different again for other spring steels. Such curves have to be used with care as the elastic properties of a steel will vary with its chemical analysis and final metallurgical structure.

#### Shot-Peening

It is a well established fact that shot-peening is highly advantageous from the point of view of improving fatigue life. The action of peening causes cold work of the surface and induces compressive stresses which act in opposition to the tensile component of stress created during flexing of the spring. The overall effect of the stress combination is to move the point of maximum stress from the surface of the spring, where it is normally concentrated, to a point a few thousandths of an inch below the surface. This is demonstrated diagram-

matically for a flat beam in Fig. 17. Thus, with a shot peened spring, the actual surface condition becomes of secondary importance whilst the metallurgical structure or condition a few thousandths of an inch below the surface is now of prime consideration.

The intensity of the peening operation has to be measured in order to ensure that all springs are receiving the correct treatment. The standard method of measurement is the Almen gauge, which consists of peening one side only of a thin steel strip whilst it is forcibly held flat. It is subsequently released and the arc rise measured. This rise is a function of the peening intensity and can be used to standardise processing conditions. There is some controversy over the reliability of this method, and fundamental research studies are being undertaken by the Coil Spring Federation Research Organisation in order to resolve the matter, and to compare the effectiveness of different types of shot, shot size, velocity and peening time.

It is well known that in a helical spring the point of maximum stress is on the inside surface of the coils due to the curvature of the bar produced by forming. This excess stress increases with increase in the ratio of wire to coil diameters. This must be borne in mind when applying the peening treatment, as it is most important to peen this inner surface properly. Since the stream of shot is normally aimed from outside the coils the inner surfaces may be partially inaccessible to the shot particles, particularly in closely coiled springs. In practice it is advisable to allow extra time of peening when the spring is closely coiled. The ideal plant is that in which there is a nozzle at the end of, and at right angles to, a long arm which can be slowly traversed along the central axis of the spring, thus giving maximum peening of the inside surface.

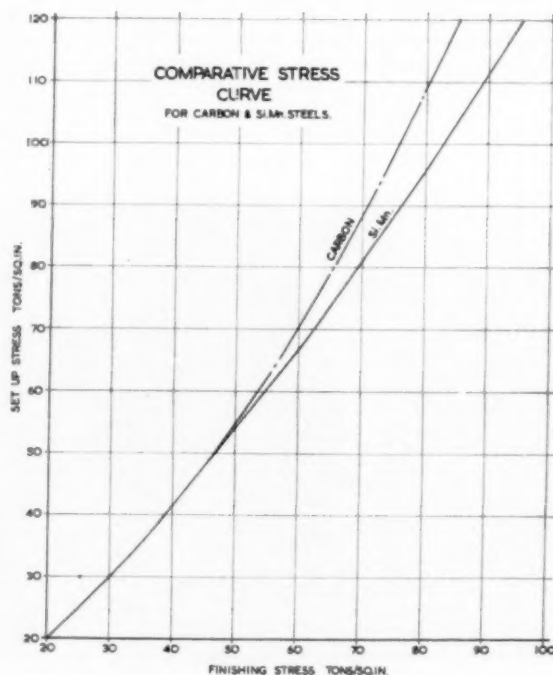


Fig. 16—Effect of pre-stressing on the final solid stress of a coil spring.

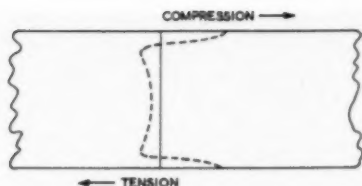


Fig. 17—Diagram showing the residual stress distribution in a flat beam due to shot peening.

Three types of shot are normally used, namely, chilled iron, steel shot and cut wire in that order of increasing cost. Chilled iron shot is cheapest, but breaks up very readily and has to be replaced once the broken fines amount to 5% of the total. Another disadvantage is the fact that the broken shot has sharp edges which tend to cut into the surface with a blasting rather than a peening action, thus inducing notches which act as stress raisers and become points of premature failing during dynamic loading. A sample containing broken shot is shown in Fig. 18.

The roughness of the shot is sometimes a controversial point, since some research workers have found an improvement in fatigue life when using grit (as against shot) and certainly the phenomenon of peening was itself discovered from observations of the effect of grit blasting on fatigue life. However, beneficial effects when utilising grit are a function of the smoothness of the edges of the grit and the type and condition of the steel being treated. The only reliable course is to use not grit but shot that has no sharp edges.

Steel shot is perhaps the most widely used material at present. It is dearer than the chilled iron, but has a much longer life. It is cheaper than cut wire, needs no initial preparation, but has a shorter life than this material.

Cut wire, as its name implies, consists of small lengths which have been cut off spring steel wires. The length of wire cut off is approximately equal to the diameter so that the particle has a square section on its longitudinal axis. Because the product has very sharp edges, it cannot be used straight away for peening and has to be treated initially by bombarding scrap steel until the edges are worn smooth. By virtue of the hardness and durability of the cut wire, this pre-treatment can take

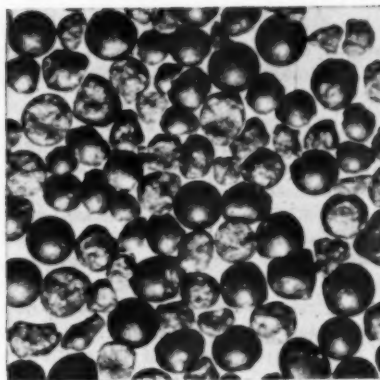


Fig. 18—Sample of shot containing broken particles.  $\times 10$

many hours and is one of the main disadvantages from the spring maker's point of view. To offset this, however, cut wire has a very long life and the amount of topping up required is more or less a function of leakage from the plant rather than from wear of the shot.

Samples of cut wire taken at various stages in its life are shown in Fig. 19. The new material is seen on the left, whilst the centre and right hand picture illustrate the appearance after 200 and 2,000 hours use, respectively. The surface condition of a well peened spring is shown in Fig. 20.

The main thing to bear in mind if one is to get a satisfactory peening action, whatever the type of shot, is to use as high a velocity as possible and a reasonable particle weight. In practice, with the types of plant available on the market, a satisfactory shot size is about 0.030 in. diameter. A further important factor, if maximum benefit is to be derived from peening, is that the spring surface must be substantially free from decarburisation, since it is not possible to induce such high compressive stresses in free ferrite or partially decarburised structures. The safest procedure is always to use ground bar for springs if they are to be subsequently peened.

#### Fatigue Life

Most problems of spring usage relate to dynamic loading where the spring is being constantly flexed. It is

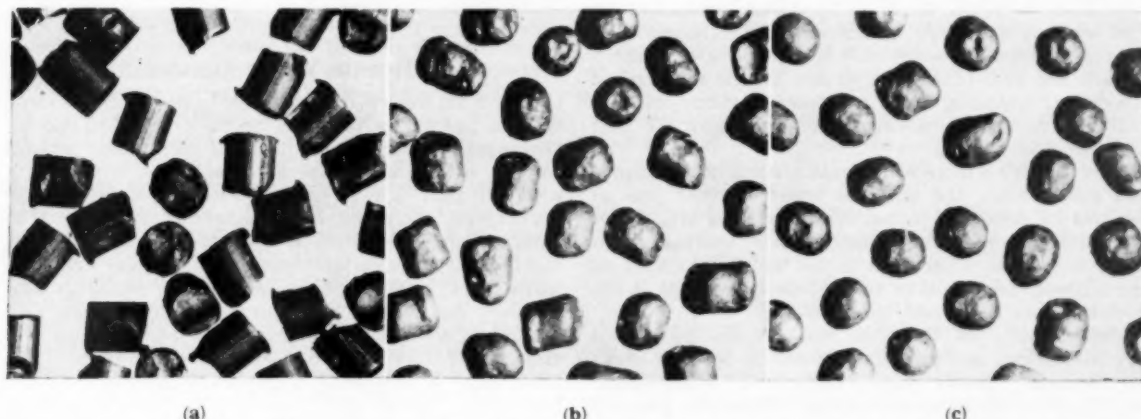


Fig. 19—Cut wire shot at various stages in its life: (a) new, (b) after 200 hours use, (c) after 2,000 hours use.  $\times 10$

a well known fact that a metal so treated may fail through fatigue even though the maximum stress to which it is submitted is not only below its ultimate strength but also below its elastic limit.

If there are any slight surface defects of any kind, including decarburisation, these may initiate a crack which will in turn ultimately cause failure. As the surface is the place of maximum stress, it is the region where failure is most likely to commence. There are two ways of overcoming this problem; one is to ensure that all surface flaws are removed, as in the case of ground bars, and the second is to shot-peen the spring so that the point of maximum stress is moved to below the surface, when the condition of the structure below the surface becomes of prime importance and the surface condition becomes secondary.

This second corrective treatment will prolong the life of the spring having certain surface defects, but in itself it will not counter all defects, and in fact a decarburised surface will prevent the full benefits of shot-peening from being obtained.

#### Corrosion Protection

This is an important requirement and one which is most usually met in heavy spring manufacture by oiling, phosphating or painting, or a combination of the last two. The satisfactory nature or otherwise of such treatments can be determined by examining a spring after it has been in use for some time in, for example, a road vehicle suspension unit or a railway wagon. Invariably, after a few years of use most traces of the coating have vanished and the metal will be corroded. This will lead eventually to corrosion pits and possibly fatigue failure.

The recent development of coatings such as the epoxy

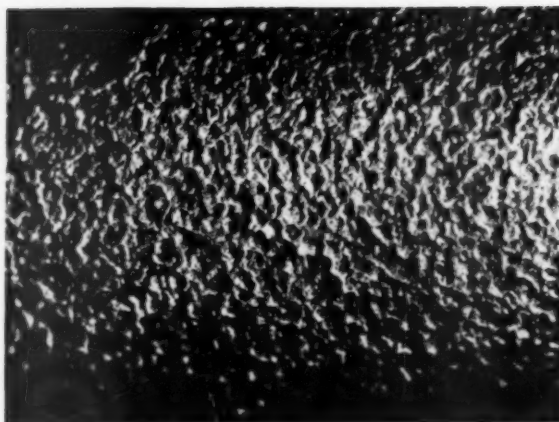


Fig. 20—The surface condition of a well peened spring.

resins has opened up new fields, and the Coil Spring Federation Research Organisation has been examining the applicability of many of these to spring manufacture. The requirements are several and arduous: viz. good adhesion, abrasion resistance, flexibility, long fatigue life, impermeability and resistance to corrosive environments. Nevertheless, some very promising coatings have been singled out which meet the requirements and further work on these and exploration of other possible coatings is being pursued.

#### Acknowledgments

The author wishes to thank the English Steel Corporation, Ltd., for permission to reproduce Figs. 7-13 and 15.

#### Russian Welding Journal Translations

WHAT is Russia's attitude to welding? Clearly the seven year plan points to an all-out drive to develop welding and mechanisation on an unprecedented scale: it is a limitless budget policy. This for example is what the Russians themselves write in a recent issue of *Avtomaticheskaya Svarka*:

"The wide adoption of these methods (submerged arc, resistance, electro-slag and gas shielded arc welding) is to be the basis on which mechanisation of welding processes in our national economy will be quadrupled between 1958 and 1965. Our country leads the rest of Europe in the use of mechanised welding methods, and we have outstripped the U.S.A. in the employment of submerged arc and electro-slag welding."

In calling for a more widespread pooling of experience and information, the editorial board of that journal declares its intention to publish a series of articles on the problems relative to welding industry mechanisation and automation, which it is hoped will draw comment and suggestions (again to be published) from all in the Soviet Union concerned with welding.

These, then, are the aims and the results of this intensive effort are published monthly, both in *Avtomaticheskaya Svarka* and *Svarochnoe Proizvodstvo*. English cover-to-cover translations of these two journals published by B.W.R.A. under a scheme sponsored by the Department of Scientific and Industrial Research

are making these results known at home, in Japan, in the U.S.A., in Germany and in many other countries throughout the world. Under their English titles of "Automatic Welding" and "Welding Production" these two authoritative journals have much to offer at all welding levels and in all welding fields. They are available at an annual subscription of £10 10s. 0d. and £5 5s. 0d. respectively from the Publications Department, British Welding Research Association, Abington Hall, Cambridge.

#### Wellman-Voest Contract

UNDER a contract placed by John Lysaght's Scunthorpe Works, Ltd., The Wellman Smith Owen Engineering Corporation, Ltd., in collaboration with Voest A.G. of Austria, are to undertake the design and supply of a complete L.D./A.C. oxygen steel-making installation at Scunthorpe, including full engineering services. The plant, which will include a 1,000-ton hot metal mixer, two 50/60-ton converters, cranes and handling machines, waste heat boilers, gas-cleaning plant, buildings and ancillary equipment, is designed initially for the production of 400,000 tons of ingots per annum, with provision for extension to 800,000 tons per annum. The total value of this order exceeds £2½ millions. This is the third contract placed since last November, when Wellman and Voest entered into an agreement for the design, supply and erection of L.D. plant in the U.K.

# National Engineering Laboratory

## Research on Materials and their Fabrication

**T**HE National Engineering Laboratory (formerly the Mechanical Engineering Research Laboratory) was set up by the Government in 1947 to serve the mechanical engineering industry by providing the scientific background necessary for continual improvement of its products. When the Laboratory was formed, it took over the work of the Engineering Division and part of the work of the Metrology Division of the National Physical Laboratory, and initiated research on other subjects. N.E.L. carries out an extensive programme of basic and applied research, complementary to that in industry, the universities and other research organisations, and, in addition, undertakes special investigations and tests by fee for industrial firms. It serves manufacturers and users of metal products and machines of all kinds, including fluid power and heat transfer equipment.

N.E.L., one of the largest laboratories of the Department of Scientific and Industrial Research, occupies a 70-acre site at East Kilbride a new town eight miles south-east of Glasgow, but the Lubrication and Wear Division is at present housed in temporary laboratories four miles away at Thorntonhall. The present staff totals some 550, of whom about half have scientific or technical qualifications, and includes mechanical and electrical engineers, physicists, metallurgists, chemists and mathematicians.

The research programme and allocation of effort are decided by the Steering Committee, with the advice of six technical sub-committees comprising distinguished engineers and scientists from industry and the universities, selected for their special knowledge and experience. Rather than spread the available effort over a large number of projects, the Committee has decided to discard or defer a number of those which have appeared in earlier programmes, and to give priority to projects which are directed towards industrial problems. Three such projects of particular importance are: investigations in the machine tool field; the development of hydrostatic power transmissions; and work on the cold extrusion of steel. At the same time, the Steering Committee is anxious that N.E.L. should look to the future development of industry, and should allocate a proportion of its time to research of a longer term nature, always, of course with practical objects in view.

The establishment and maintenance of effective collaboration with industry is the greatest single problem facing the Laboratory. On one hand the Laboratory must seek to understand the requirements of industry and anticipate its needs. On the other hand, industry must be encouraged to see for itself what facilities and experience are available, and to ensure that the Laboratory is kept informed of urgent industrial problems. The Steering Committee feels that whilst the facilities at N.E.L. are the most up-to-date of their kind in the world, they will be full effective only when industrial firms make more direct use of them than at present. An opportunity of seeing the facilities and the

work in progress was provided by the recent Open Days, which were attended by more than 2,000 visitors. Reference is made in the following pages to a number of items selected as likely to be of interest to readers.

### THE FORMING OF MATERIALS

The manufacture of almost all metal articles involves plastic (permanent) deformation of the material. Most metalworking processes developed largely by trial and error based on earlier production experience, often with little understanding of their mechanism. Systematic investigations are being carried out to provide a better understanding of the mechanism of plastic deformation so that economies in plant design and more efficient operation may be achieved.

Production processes fall into two groups: formation processes, where the metal is squeezed into the required shape; and processes, such as turning and milling, where unwanted metal is removed. Both types of process are being investigated with ferrous and non-ferrous metals to determine the nature and relative importance of the factors which govern plastic deformation in them.

### Cold Extrusion of Steel

The production of pins, cartridge cases, shells and other hollow components by extrusion from an unheated steel billet is carried out on an appreciable scale in Germany and the U.S.A., but very little use has been made of this process in Britain, partly because so little detailed information is available. The cold extrusion process offers a high production rate, a product with a good surface finish and consistent dimensions, and substantially improved mechanical properties as a result of cold working: in addition, the use of this process in place of machining gives a substantial saving in material.

An experimental study of the cold extrusion of steel has been carried out to provide a better understanding of the process and its limitations; data are now available to help firms in the design of tooling and the selection of the best material and extrusion conditions for particular products.

The investigation has been concerned with the effect of the process variables on the extrusion pressure, the flow of the metal and the properties of the product: the process variables studied include extrusion ratio (the ratio of the cross-sectional area of the billet to that of the product), ram speed at impact, lubrication, shape of die and punch, and the length-to-diameter ratio of the billet. Most of the work has been done with a 0.15% carbon steel but the pressures required for the extrusion of thirteen types of carbon and alloy steel over a range of reductions have also been determined. Annealed billets of 1 in. diameter were used; after phosphating, they were lubricated with a metallic soap or molybdenum disulphide.

The tests were carried out in a 150 ton crank press

which has a variable stroke from 3 to 12 in.; speed can be varied from 10 to 60 r.p.m., giving ram impact speeds ranging from 2 to 16 in./sec. Ram stroke and extrusion load were recorded continuously throughout the extrusion operation and various types of gridded billet were used to study metal flow.

All the steels investigated could be extruded, the reduction obtainable being limited only by the maximum permissible stresses in the tooling. These restricted the extrusion ratio to  $6\frac{1}{2}$  for steels containing up to 0.25% carbon and for a 3% nickel steel, to 4 for a 3% chromium steel, and to 3 for a 1% carbon steel. The carbon steels were found to work-harden more than the alloy steels, and the extrusion pressure increased with increasing carbon, manganese, silicon and molybdenum content.

The investigation has shown that, for a given extrusion ratio, the extrusion pressure is about the same for the forward extrusion of rods and tubes, but is lower for the backward extrusion of cans. The stress on the punch when extruding cans (and on the die when forming rods and tubes) varies with the degree of reduction and has been found to be a minimum for an extrusion ratio of about 2, the exact value depending on the type of steel.

The effect of the shape of the die entry has also been studied. With a conical-entry die, decrease in the cone angle reduced the maximum extrusion pressure and reduced the rate of build-up of pressure, due to the billet filling the die cavity before the rod or tube was extruded; decrease of the cone angle below  $60^\circ$  did not produce any further reduction in maximum pressure. The effect of radiused-entry dies on the maximum extrusion pressure was similar but less marked, a die with an entry radius of 0.25 in. having a pressure/stroke characteristic similar to that of a die with a  $120^\circ$  cone entry. With good lubrication the surface finish of a product extruded through a sharp-edged die is better than the product from a conical-entry die, which tends to retain the finish of the billet.

In the extrusion of cans, a punch with a flat-nose profile having an edge radius of 0.05 in. gave slightly lower maximum extrusion pressures than a punch with a nose profile having a 1 in. radius chamfer.

As the ram impact speed increased, the diameter of the product extruded from the same sharp-edged die was found to fall. For example, when extruding rod of  $\frac{1}{2}$  in. nominal diameter, the product was 0.007 in. undersize at a ram speed of 2 in./sec. and 0.010 in. undersize at a speed of 16 in./sec.; more accurate products were obtained by using conical-entry dies. Within the range of ram speeds investigated (2 to 16 in./sec.) speed had little effect on the maximum value of extrusion pressure, the pressure/stroke characteristic, or the hardness over the cross-section of the product.

Further work on several aspects of the cold extrusion of steel is to be carried out, particularly the effect of higher ram speeds and different ram-displacement/time characteristics. It is also hoped to study the effect of the process variables on the rise in temperature in the billet and product caused by the conversion of the work of deformation into heat.

#### Cold Closed Die Forging

In the forging process metal is compressed between dies to produce an item of the required shape or to give it improved mechanical properties. It may be subjected to unrestricted flow between parallel platens as in upsetting, to partially restricted flow within semi-closed

dies as in fullering, or to fully restricted flow within closed dies as in the production of complicated forms.

Forging has been regarded as an essentially hot working process. This was partly due to the limited capacities of the early presses which necessitated the heating of material to lower its resistance to deformation and thus permit the forging of sizeable products. The tradition of hot working has persisted, even to the forging of those components which from metallurgical and size considerations could be deformed satisfactorily at room temperature.

Hot working introduces many complications quite apart from the financial considerations of heating the material. The presence of scale affects both heat transfer and friction conditions; the consequences of the latter being particularly serious in the closed die forging of thin sections. In attempting more precise forms an allowance has still to be made on dimensions to accommodate thermal contraction on cooling, the amount depending on the complexity of the part, draft angles have to be sufficient to allow the product to be ejected easily and hollow cores are normally avoided. All this necessitates additional machining and a greater wastage of metal which, added to the weight of metal already lost in flash, is of considerable economic significance.

Cold forging techniques offer scope for improved metal utilisation by manufacture of more accurate products, coupled with the possibility of enhanced mechanical properties of the material due to cold work. The forging industry has little background experience of this new technique and the work at N.E.L. is aimed at providing the basic data necessary to implement the process.

Tests are being conducted to determine how simple cylindrical specimens in a range of metals deform to fill conical and pyramidal cavities in dies during press forging. Deformation patterns corresponding to different stages in the filling of the die cavity are obtained by means of split and gridded specimens. The volume of material displaced laterally and axially within the die cavity is being determined throughout the deformation process. The results obtained for the compression of a cylindrical specimen of 1 in. diameter and 0.563 in. high within a conical cavity of  $90^\circ$  including angle suggest that in the early stages of compression metal flows axially rather than laterally, this is followed by an intermediate stage when the flow laterally is greater than that axially, and the final stage where the flow is again almost entirely axial.

The loads and energies required to deform the specimen have also been determined at stages throughout the filling of the cavity. There is a marked increase in load required during the final stages of filling, depending on the relative shapes of the initial specimen and the cavity. The effect of specimen geometry and die geometry is being studied in some detail and the effect of flash on the forging load ascertained.

In the manufacture of a number of components it will be necessary to produce an off-set or flange by an upsetting operation or a change of profile by a cold heading operation, both between closed dies. The machining requirement will normally be a minimum when the draft angle is zero but it may not always be possible to eject the components under such conditions. A study is being made of the effect of small draft angle on the press loads required to compress simple specimens to fill the die and to eject the forged component.

Cylindrical specimens in a range of metals are being compressed into a cylindrical cavity with draft angles ranging from  $0^\circ$  to  $9^\circ$ . The press loads required to fill the cavity and to eject the forged component are measured.

### Forming Materials Under High Hydrostatic Pressure

In metal working processes such as extrusion, rolling and wire drawing, deformation occurs under a large component of hydrostatic stress. Extrusion is probably the best example of a process in which the metal may be given, without fracture, very great reduction in area. This reduction indicates a ductility much greater than that shown by a standard tensile test, and suggests that the large component of hydrostatic stress built up in the extrusion billet enables large strains to take place without fracture.

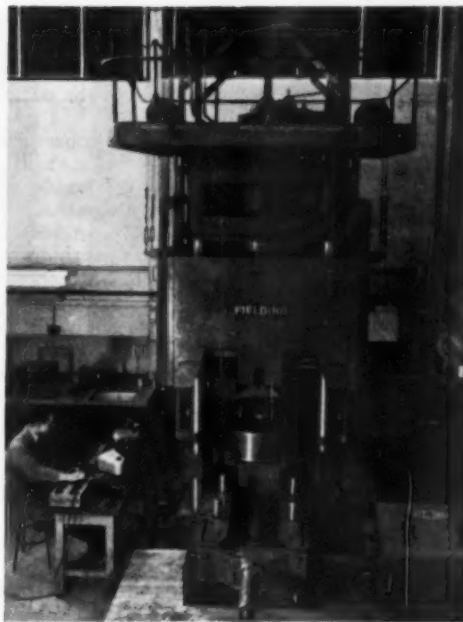
This effect has been confirmed by carrying out mechanical tests, e.g. tensile tests, on metals in a pressurised fluid. These experiments showed that for most metals a gradual increase in ductility, i.e., strain to fracture, occurs with an increase in the ambient hydrostatic pressure. In the case of zinc, however, a marked and sudden change in ductility takes place over a narrow pressure range.

Further confirmation has been obtained by a series of tests in the conventional extrusion process. The hydrostatic component of stress in the billet during extrusion increases with the extrusion ratio and tests were carried out on magnesium to determine whether the cracking of the product, which occurs at low extrusion ratios, could be eliminated by increasing the extrusion ratio and thereby increasing the hydrostatic component of stress. It was found that at an extrusion ratio of 4 (extrusion pressure 33 tons/sq. in.) the metal emerged through the die in badly cracked sections and exhibited very brittle behaviour. As the extrusion ratio was increased there was a gradual reduction in cracking until, at an extrusion ratio of 16 (extrusion pressure 60 tons/sq. in.), cracking was almost completely eliminated.

In view of the above effects and of the fact that there are many brittle materials which cannot be satisfactorily extruded in the conventional manner, an experimental study has been made of the extrusion of some such materials in a pressurised fluid.

Materials such as magnesium and bismuth have lattice structures which severely limit their capacity for cold work, particularly in the cast state. Results have indicated that, for magnesium and bismuth, a superimposed hydrostatic pressure of 2 to 3 tons/sq. in. may be adequate to suppress brittle behaviour of these metals at low extrusion ratios. Some experiments with 60/40 brass are also encouraging, but much higher hydrostatic pressures may be required to produce satisfactory extrusions.

It is hoped to develop these techniques to the stage where high-pressure forming can be used industrially. One important application would be the manufacture of nuclear fuel element cans. These can be produced by hot forming magnesium alloys, but improved mechanical properties obtained with cold forming operations would be of considerable practical importance. The possibility of extruding cans of pure beryllium is also attractive, since beryllium is a notoriously difficult and dangerous material to work using conventional machining processes.



300-ton press for studying the effect of high hydrostatic pressure on the plastic properties of materials.

A study of the properties of metal which had been extruded under superimposed hydrostatic pressure, was restricted by the small scale of operation that was possible since the extrusion apparatus fitted into a  $1\frac{1}{4}$  in. bore high-pressure container and the extrusion slugs were only  $\frac{3}{8}$  in. diameter. Increased press capacity is now available and larger scale work using a high-pressure container of 3 in. bore and extrusion slugs 1 in. in diameter will be carried out. This will permit lengths up to 12 in. of rod and tube to be extruded and subsequently tested.

A parallel investigation is being carried out into the extrusion of metals by fluid pressure. By this method the slug to be extruded is only in contact with the die face, elsewhere it is surrounded by a reservoir of fluid. The fluid is pressurised and the metal is extruded through the die into atmospheric pressure. This process eliminates friction at the container wall and provides a large source of high-pressure fluid for lubricating the die face, thereby minimising die friction also. The effect may be to reduce considerably the extrusion pressure required. This is of particular interest in the cold extrusion of high-strength metals and may permit higher reductions within the safe working stress range of the tools.

### PROPERTIES OF MATERIALS

To make the best use of engineering materials, designers must know how they will behave under the stresses to which they will be subjected in service. The stresses may be caused by steady, repeated, or shock loads; they may be simple or complex; and they may occur at atmospheric temperature or at high or low temperatures.

Since most of the service failures of engineering components are the result of repeated loading, particular

attention is paid by the Materials Division to basic and applied investigations of the fatigue of metals. The work ranges from fundamental physical studies of the mechanism of fatigue to investigations of the strength of components such as pin joints

Another important part of the work is concerned with creep—the slow elongation of metals under steady load at high temperatures. Research on creep under complex stress systems is being carried out to provide basic data on the behaviour of typical engineering materials under these conditions. Investigations of creep under simple stress systems have formed part of the Laboratory's research programme for many years but, because of shortage of space the work has been carried out at the N.P.L. Work has now started on the construction of a new laboratory which will permit the much needed expansion of research on high temperature materials.

The formation of the Creep Information Centre was announced last June, its purpose being to correlate data from various sources on the properties of materials at high temperatures, and to make the results readily available to British industry.

### Growth of Fatigue Cracks

In certain components and structures it may be inevitable that small fatigue cracks will form at low alternating stresses. Such cracks are initiated at geometric stress raisers (sharp corners, notches, rivet holes, etc.), inclusions in welded joints, or may be a consequence of fretting. In some cases the use of sophisticated inspection techniques has resulted in cracks being detected in components which had previously been assumed uncracked.

The rate of growth of the crack will depend on the material and the imposed working loads and it may be very slow. Thus, although cracks may form very quickly, the component or structure may still have a long useful service life before the cracks reach such a size that catastrophic failure occurs. A knowledge of the stresses required to cause such cracks to grow and their subse-

quent rate of growth, together with an adequate inspection procedure, is necessary for an efficient design involving the most economical use of material.

To study this problem at N.E.L., tests have been carried out using sheet specimens, in which a crack is initiated by introducing a small central slit about  $\frac{1}{4}$  in. overall length. The specimen is then subjected to a loading cycle such that the loading is never compressive. The stresses required to cause cracks to grow are low, for example, for mild steel  $5 \pm 1\frac{1}{2}$  tons/sq. in. or for a 4 $\frac{1}{2}$ % Cu aluminium alloy  $2 \pm \frac{1}{2}$  tons/sq. in. will cause cracks to grow across a 10 in. wide specimen in about  $10^7$  cycles.

The rate of growth depends on both the fracture mechanism of the material at the crack tip and on the crack-length/sheet-width ratio. It has been shown that if this latter ratio is less than  $\frac{1}{4}$  the crack can be considered as growing in an infinitely wide sheet. For larger ratios, the stress and strain distributions at the crack tip are no longer independent of this ratio. Analysis of the experimental results of a series of tests on 10 in. wide specimens of various materials showed that for overall crack lengths up to  $1\frac{1}{4}$  in. the rate of growth was given by:

$$\frac{dl}{dN} = \frac{\sigma^2 l}{N_s}$$

where  $N$  = millions of stress cycles

$\sigma$  = nominal alternating stress based on gross area

$l$  = crack length

and  $N_s$  = constant depending on material and mean stress.

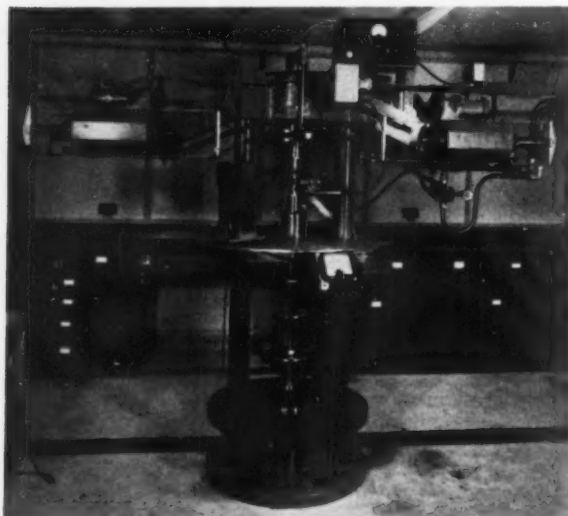
No correlation was obtained between a material's ability to withstand fatigue crack growth and any other mechanical property or with the plain fatigue strength.

It is important to note that extrapolation of the rate of growth to crack lengths longer than actually studied may be dangerous, as the mode of fracture at the crack tip may change as the crack grows. For example, at a certain crack length brittle fracture or fast cyclic tearing may occur. Consequently, from a design aspect, the ability to withstand both static and cyclic fast fracture conditions up to specific crack lengths is a necessary condition. In general, materials having a low static ductility should be avoided on account of fast cyclic and brittle fracture, but high static ductility does not necessarily imply good resistance to fatigue crack growth. The crack lengths at which fast cyclic fracture occurs are being studied by using wider specimens (viz. 30 in. wide). In addition the effect of sheet thickness is being studied.

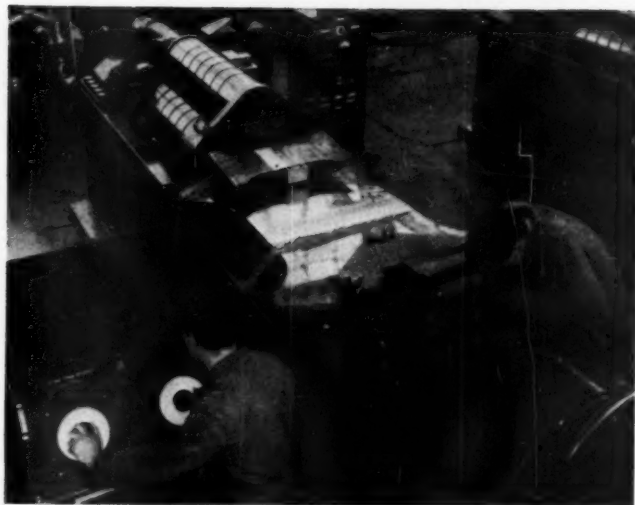
Present work has been restricted to measurements of crack growth under constant stress cycles. In practice the applied cyclic loads may vary either in a regular or random manner. The problem of crack growth under such varying stress cyclic amplitudes is to be studied.

### Effect of Fretting on Fatigue Strength

Fretting is a form of damage occurring between mating surfaces which have small oscillatory movement relative to each other. Even nominally flat metal surfaces only make true contact at a number of small high-spots, at which severe local deformation is brought about by relative displacement. Under oscillatory conditions, shallow surface fatigue cracks and loose metal particles



N.E.L. combined-stress machine for research on the plastic properties of materials.



Measuring strain distribution in a large sheet in a 60-ton fatigue machine.

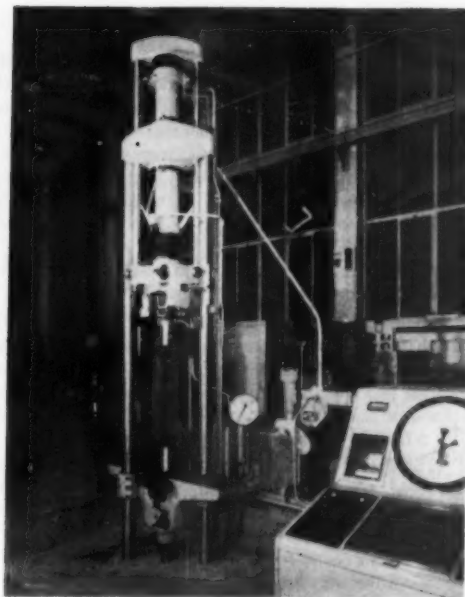
are produced. If the body of the metal is subjected to fatigue stress, large cracks may propagate from regions of surface damage and cause failure of the part at nominal stresses much lower than would be required to cause failure in the absence of fretting. In the presence of air, the metallic debris is rapidly oxidised to give abrasive material which is largely responsible for fretting wear. It is, however, in the initial stage, when metal-to-metal contact is greatest, that the main fatigue damage occurs.

The investigation in Materials Division has been concerned with the basic nature of this fretting-fatigue damage. The work has been carried out largely on a duralumin-type alloy, B.S. L65, but has also included a mild steel and a high tensile steel En 26. A method has been devised of fretting the surface of a specimen under controlled conditions while the specimen is subjected to simultaneous fatigue stressing.

For the aluminium alloy, it has been found that, under low contact pressure ( $\frac{1}{4}$  ton/sq. in.), the range of surface fretting movement required to produce maximum fatigue damage is only about 0.0003 in. Further increase in the range of movement causes no further reduction in fatigue strength. Under tensile mean stress in the specimen, fatigue failure will occur at less than  $\frac{1}{2}$  of the alternating stress at which it will occur in the absence of fretting, and, under zero mean stress, at about  $\frac{2}{3}$  of that alternating stress.

Under high contact pressures, fretting is suppressed, except at the edges of the contact areas; the reduction in fatigue strength then obtained depends on the tangential force between the surfaces. If this force is low, the reduction in fatigue strength is small, but if it is high enough to cause substantial rupture of the adhesion between the mating surfaces, severe fatigue damage results.

The greatest reductions in fatigue strength are brought about by fretting which does not produce much abrasive wear. From the point of view of inspection, this means that apparently slight fretting damage must nevertheless be regarded as a potential source of fatigue failure, especially in aluminium alloys.



20-ton fatigue machine (the rate of growth of fatigue cracks in 10 in. wide sheets is being measured)

Under various fretting conditions, it has been found that the surface fatigue damage is, in general, fully developed after about  $\frac{1}{3}$  of the total fatigue life. Significant fatigue damage can, however, occur much earlier than this, e.g., in the aluminium alloy such damage has been found after only 4,000 fretting cycles under a contact pressure of  $\frac{1}{4}$  ton/sq. in. and a relative surface movement of 0.00035 in. Paradoxically, it appears to be more difficult to propagate a large fatigue crack from the surface damage caused by only a few thousand cycles of fretting when the fretting is applied with the specimen under tensile mean stress than when it is applied with the specimen under zero mean stress.

The early damage, due to fretting, has been shown to take the form of shallow cracks inclined to the surface. The pitting occurring in fretted areas seems to be due largely to coalescence of these surface cracks; the geometrical notch effect of these pits is not considered to be a primary cause of the development of major fatigue cracks.

In a vacuum, both the onset of surface damage and the propagation of major fatigue cracks are delayed. The more rapid development of damage in air is evidently due to an auxiliary corrosion-fatigue effect.

In the mild steel, the surface cracks, due to fretting, do not propagate nearly so readily as in the aluminium alloy; mild steel appears to be relatively insensitive to fretting-fatigue damage except at high contact pressures. The fretting-fatigue strength of the high tensile steel is only of the same order as that of the mild steel. Under certain conditions it may even be lower than that of the mild steel.

Further work will include investigations of the effect of atmosphere and of various methods of reducing fretting-fatigue damage.

### Fatigue Strength of Pin Joints

The joint formed by connecting fork and tongue members by a transverse pin is the basis for many engineering connections, such as bolted and riveted joints, as well as being a widely used joint in its simple form. Under fatigue conditions such a joint has long been known to have a very low strength, resulting in inefficient use of material. A tongue of aluminium alloy L 65 of cross section  $2\frac{1}{2}$  in.  $\times$   $\frac{3}{4}$  in. loaded through a steel pin  $\frac{3}{4}$  in. diameter which was a sliding fit in a reamed hole, had a fluctuating load carrying capacity of only about 1 ton for a life of 10 million cycles.

Research into methods of improving the strength of such joints has shown that by having a sufficiently high interference fit between the pin and tongue, and using a larger pin than is suggested by elastic stress analysis, it is possible to increase the fluctuating load carrying capacity by a factor of 8 or more at 10 million cycles.

Interferences of 0.008 in./in. of diameter require several tons to assemble, and this is frequently impracticable for assembly purposes, and also results in a permanent joint that cannot easily be dismantled for maintenance or repair. Interference fit bushes, making due allowance for the compressibility of the bush, can however be pressed in prior to assembly with clearance fit pins. Such assemblies give strengths comparable with those having solid pins and similar interferences.

### Fatigue Testing of Large Components

A novel technique has been developed to enable rotating-bending tests to be simulated without any rotating parts; it has been developed particularly for fatigue tests on railway axles. The wheel-and-axle assembly is excited in bending at its fundamental resonant frequency by two electro-magnetic vibration-generators, displaced mechanically 90° to each other. These vibrators are fed by currents with a 90° relative phase-shift, and a rotating-bending force is therefore obtained.

A capacitance pick-up in a regenerative loop maintains oscillations exactly at the resonant frequency of the wheel-and-axle assembly. This frequency drops when a crack appears and this may be used to stop the test automatically. A more sensitive automatic cut-out monitors the current in the vibrators; a drop in the amplification factor of the system when a fatigue crack grows lowers the vibrator impedance and causes the current to increase when the vibrator is energised from a constant-voltage source. This constant-voltage source results from the stabilising of the amplitude of oscillation by diode limiters. The frequency of vibrations and axle strains are monitored throughout the test and an electronic counter records the total stress reversals to failure.

### High-Temperature Fatigue

The high-temperature fatigue section is concerned with testing materials under fatigue loading at temperatures above room temperature. The main part of the work is at present being carried out on materials of interest to the aircraft industry.

Specimens of Nimonic 90 material, both solid and with longitudinal holes, are being tested in direct stress in Haigh machines at 850° and 900° C. It appears that the reduction in strength due to the presence of the holes is dependent on the method of forming the holes, whether

in the sintering or extrusion processes, or by drilling or spark machining.

The fatigue properties of brazed joints in Nimonic 90 at 800° C. are being determined in tests with a limited number of brazing alloys. These tests are also being carried out in direct stress in Haigh machines.

The fatigue properties of three titanium alloys are being determined in Rolls-Royce rotating bending fatigue machines at room temperature, 300° C. and 400° C. The specimens are both plain and notched. Tests on the plain specimens have been completed and it is proposed to run some larger rotating bending fatigue specimens for comparison. Work is proceeding on the notched specimens.

Tests have just been completed on plain and notched specimens of a high strength steel (Bacc 165) at room temperature and 250° C. with a fluctuating direct tension stress of  $P \pm P$  within a range of  $10^4$  to  $10^8$  cycles. These tests were carried out in an Amsler Vibrophore. There would appear to be a large drop in stress between plain and notched specimens at both temperatures. For the notched specimens the difference in temperature appears to have had little effect on the strength of the steel but there appears to have been a definite drop in strength at 250° C. in the plain specimens.

Work has been started on investigating the influence of changes in temperature on the pattern of fatigue results.

### Creep Behaviour of Engineering Materials

#### *Mechanics of Creep*

The experimental work on the creep behaviour of typical engineering materials includes investigations of creep under complex stress systems with both simple and general loading conditions at elevated temperatures; relaxation under complex stress systems at elevated temperatures; creep to fracture under complex stress systems with and without the addition of fatigue causing stresses; and creep of model structures. In addition, the nature of creep at very low stresses is being examined. Data from all this work is being used in analytical approaches to the determination of the stresses and displacements, as functions of time, of typical machine elements or structures subjected to externally imposed systems of loading, or displacements under conditions where creep arises.

#### *Creep under Complex Stress Systems at Elevated Temperatures*

Creep or time-dependent plastic flow, occurs under complex stress conditions at elevated temperatures in many components of power plant. For adequate design of such components, knowledge is required of the relations between creep rate, creep strain, stress, time, and temperature under complex stress systems. The object of this part of the work at N.E.L. is to establish these relations.

At the present stage of the work the creep characteristics of typical engineering metallic alloys have been examined under

- (a) simple-loading complex-stress systems;
- (b) generalised-loading complex-stress systems, the stress systems being altered at various stages of the creep tests;
- (c) relaxation conditions in which the total strain is maintained constant, the complex stresses being continuously reduced to satisfy this condition whilst their original ratio is maintained; and

- (d) stress conditions leading to complex-stress creep fracture. The effect on complex-stress creep fracture under a given stress system of previous periods at higher stress levels, and also the effect of vibratory stresses causing fatigue, are being examined.

#### *Creep of Structures*

To achieve economic design of structures which have to operate at elevated temperatures, it is necessary to recognise that in certain circumstances, some degree of creep strain must be allowed to occur. Because of the generally complicated stressing occurring in such structures there are uncertainties in the application of experimentally derived relationships of creep strain, creep rate, stress and time. To resolve such difficulties, tests on model structures are helpful. The present investigation seeks to establish the bases of the behaviour of structures under such conditions by means of tests on relatively simple, but representative structural elements. In this work a magnesium alloy is being used; at room temperature it simulates the creep behaviour of many metals at high temperature and shows little or no time independent plastic strain within the creep range of stress being used.

#### *Creep at Low Rates of Strain*

The torsion-creep characteristics of a group of engineering metallic alloys are being examined at creep rates of the order of  $10^{-6}$  to  $10^{-9}$  per hour, i.e. within the range of "micro-creep."

#### **Creep Information Centre**

The Creep Information Centre has been set up at N.E.L. so that data on the strength properties of engineering materials at elevated temperatures may be made readily available to industry from one source. It is hoped that all producers of high-temperature materials and users of these materials will pool their information. Commercial security may restrict the publication of some of the data, but, subject to this consideration, it is intended to issue high-temperature data for British materials in an agreed form.

In the first place all the available data on creep and rupture properties of conventional high-temperature materials are being collected and tabulated. Later it is intended to include data on all mechanical properties of these materials and also information about test procedures and testing machines; data on foreign materials may also be included.

It will be some time before the scheme becomes fully effective but it is hoped that eventually C.I.C. will become the national centre for data on the mechanical properties of British and foreign high-temperature materials and test methods.

It is intended that the Centre will perform some of the following functions:

##### **(1) High-Temperature Materials**

- (a) To collect experimental data on creep and other mechanical properties (including high temperature fatigue properties) of high-temperature materials in the form of original curves and laboratory reports, published papers, catalogues and trade literature.
- (b) To tabulate these data and make them available to industry.

(c) To collect British and foreign specifications for standard high-temperature materials.

##### **(2) Equipment and Test Procedures**

- (a) To collect details of British and foreign testing machines for high-temperature work, and information about test procedures.
- (b) To produce lists of references on particular aspects of high-temperature testing and mechanical properties.
- (c) To prepare a manual on the testing of high-temperature materials.
- (d) To organise discussions on high-temperature test procedures.

##### **(3) Liaison with Other Organisations**

- (a) To maintain contact with all committees in the U.K. concerned with high-temperature materials.
- (b) To maintain contact with all British high-temperature laboratories through a technical liaison officer, with a view to co-ordinating the development of testing equipment and techniques.
- (c) To prepare a summary of the major projects and test programmes of British high-temperature laboratories.
- (d) To make contact with overseas organisations so as to foster international co-operation in investigating problems relating to the use of engineering materials at high temperatures.

##### **(4) Museum of High-Temperature Failures**

- (a) To collect samples (with case histories) of failures of high-temperature materials from industry and other organisations.

### **Society of Furnace Builders**

At the annual general meeting of the Society of Furnace Builders, which enjoys the membership of some twenty-one of the leading furnace builders in G.B., Mr. H. Southern retired from the chairmanship of the Society after serving it with distinction for sixteen years. Mr. Southern, who is managing director of G. P. Wincott, Ltd., Sheffield, has, during his period of office, done much to consolidate the furnace industry, thus enabling it to speak with one voice on Governmental and trade association matters.

On behalf of the industry he negotiated with the Government on the disposal of surplus furnaces at the end of the war in 1945; on the export of industrial furnaces in the national effort of 1947; and on the shortage of materials which arose in 1948. He collaborated with others in the formation of The Refractory Users' Federation, a national organisation representative of the various industries engaged in the supply installation and maintenance of coke-ovens, gas retorts, industrial furnaces, boiler settings, etc.

The Members of the Society of Furnace Builders are greatly indebted to Mr. Southern for his constant care of the Society's interests and for the enormous amount of work he has done during his long term of office. In recognition of his services they have appointed him the first president of the Society. Mr. C. G. Pettit, assistant managing director of The Incandescent Heat Co., Ltd., succeeds Mr. Southern as chairman.

# New Ultra High Strength Steels for Use at Elevated Temperatures

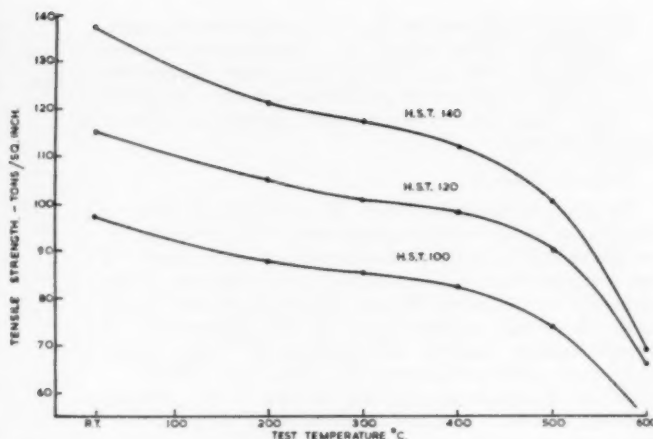


Fig. 2—The tensile strength of HST steels at room and elevated temperatures. Initial condition: oil hardened and tempered at 600° C. for 1 hour.

A NEW series of ultra high strength steels for use at high temperatures has been developed by Samuel Fox & Co., Ltd., a subsidiary of The United Steel Cos., Ltd. The steels have been designed to give tensile strengths of between 100 and 140 tons/sq. in. after tempering at up to 600° C. In addition to permitting higher operating temperatures to be considered in design, compared with steels which are currently being specified for these strength levels, the high tempering temperature will yield maximum stress relief and, therefore, greater dimensional stability. There are at present three steels in the new series, of which the first is a commercial alloy already in production. This steel has a tensile strength of 100 tons/sq. in. in the air-hardened and tempered condition. Formerly described as Fox 769, it has now been renamed HST 100.

The two new steels in the series have been obtained by

small compositional changes in the basic HST 100 analysis, but there is no increase in the carbon content, while use has been made of a combination of solution hardening and improved tempering resistance. The steels are known as HST 120 and HST 140, and have tensile strengths of 120 and 140 tons/sq. in., respectively, at room temperature; it has been possible to reduce the carbon content of HST 120 to 0.30%. Both these steels can be hardened in either air or in oil, depending on mass, and all three in the series have silicon contents below 0.40%.

Fig. 1 shows a comparison of the tempering characteristics of the HST steels, and Fig. 2 illustrates the elevated temperature tensile properties in the range 20-600° C. It will be seen that, at the preferred tempering treatment of 600° C., tensile strengths of 98, 115 and 137 tons/sq. in., respectively, have been obtained at room temperature, combined with remarkably good ductility figures. Still higher tensile properties can be obtained, of course, by small adjustments to the tempering treatment. HST 140 has shown a 13% elongation and a 41% reduction of area at a strength level of 137 tons/sq. in., and it is felt that these are fairly typical figures.

The HST steels can be produced in the form of billets, blooms and slabs for forging and re-rolling, and in bars for forging or machining. Bars can be supplied either in the annealed or fully hardened and tempered conditions. Experiments are taking place to produce sheets down to 0.064 in. thick in all three qualities, but these are not yet generally available.

Application for the HST steels are expected to be found in the aircraft and rocket industries, although HST 140 could probably be used to advantage as a hot die steel.

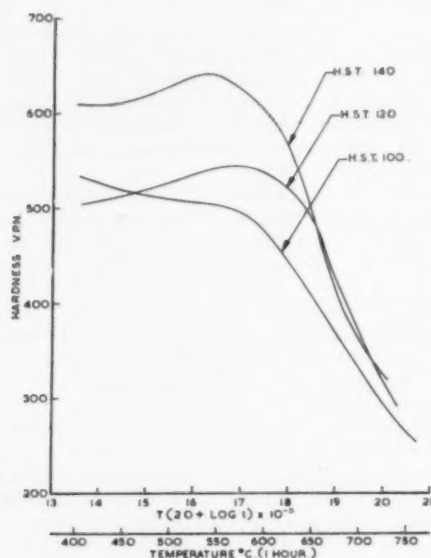


Fig. 1—The tempering characteristics of HST steels.

## Finishing Line Order

SCHLOEMANN AKTIENGESellschaft, Düsseldorf, is to supply the Forges de Clabecq S.A., Clabecq, Belgium, with the complete finishing line plant for a 9 ft. 4 in. heavy and medium plate mill. Included in the equipment is a hot leveller, rotary trimming shear, two rocking shears, roller tables, a cooling bed with plate turner, manipulators, pilers and scrap handling gear.

# Heat treatment

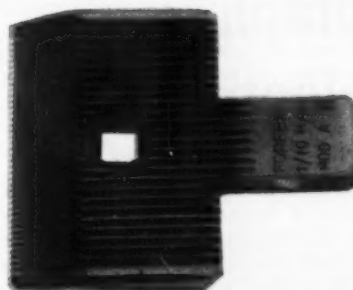
Cucumbers grow firm and ripe in the controlled heat of the greenhouse — and metal parts receive the best heat treatment in 'Cassal' salt baths.

With salt baths as with greenhouses, what counts is experience. The 'Cassal' Heat Treatment Service has long experience in carburising, heat treatment, tempering, martempering and austempering.



Write to:  
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# EFCO-UPTON

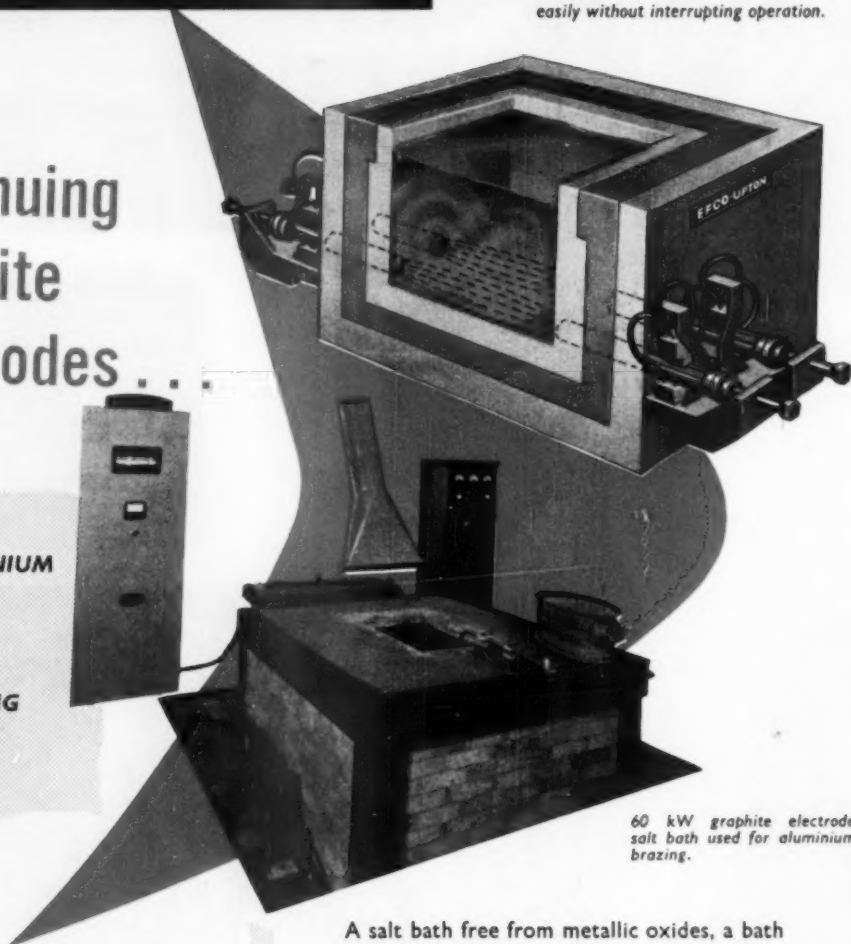
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continuing  
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REP/RJ067

# NEWS AND ANNOUNCEMENTS

## Industrial Training in Operational Research

THE British Iron and Steel Research Association announces the introduction of a graduate apprenticeship scheme for specialised training in operational research. The purpose of the scheme is to train recruits not only in the specialist techniques, but also in the practical art of applying these methods to actual industrial problems.

During the two-year course, the apprentice will be regarded as a temporary member of B.I.S.R.A. staff at a salary of £700 per annum at the age of 21, with an extra £25 per annum for each year above that level. Training will consist of day-to-day experience as a member of a team engaged on actual problems in the steel industry followed by a more formal course in techniques, arranged in collaboration with the London School of Economics. The course will culminate in an examination for the Diploma in Operational Research recently instituted by the London School of Economics. The basic qualification for an apprentice is a good degree in a pure or applied science, mathematics, or statistics.

B.I.S.R.A.'s operational research department, which is sponsoring the scheme, was started in 1946, and has a very wide industrial experience of operational research. The new scheme provides an unusual opportunity for the ambitious man to acquire a first-class training in a rapidly expanding field. Further particulars, including an explanatory leaflet, can be obtained on application to B.I.S.R.A.'s personnel officer, at 11, Park Lane, London, W.1.

## Lecture Courses

A SPECIAL course on corrosion and protection of metals, organised by the Division of Metal Science at the Borough Polytechnic, Borough Road, London, S.E.1, will be run on one afternoon and one evening a week during the three terms of the session 1960-61. The course will deal with chemical and electrochemical principles, and with metallurgy in the afternoons; and

with corrosion and protection in the evenings. At the end of the course, students will be able to sit for the Polytechnic Certificate examination. The first lecture will be on Monday, September 26th.

In addition to the above course, three special evening courses have been organised for the winter term. On Thursdays, commencing October 6th, a six-lecture course on recent developments in electrolytic metal finishing, will be held. This is intended for chemists, metallurgists and engineers interested in metal finishing, and will cover recent developments in nickel, chromium and precious metal plating, and anodising of aluminium and its alloys.

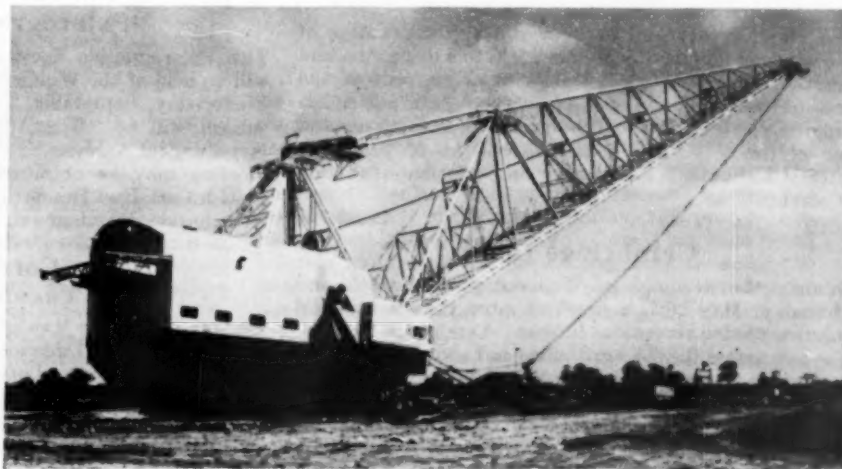
A second course of ten lectures beginning on Friday, October 7th, will deal with refractories—their manufacture, properties and uses. This course is for chemists, metallurgists and engineers interested in refractory materials, and will cover the constitution and physical and chemical properties of acid and basic refractory materials; thermal insulating materials; ceramic materials; and the design of high temperature equipment.

The last course, on the metallurgy of semi-conductors, will consist of eight lectures beginning on Tuesday, October 25th. This course is intended for graduate metallurgists, physicists, chemists and electrical engineers engaged on work in the semi-conductor field. It will cover physical principles; melting and freezing; zone refining; growth of high perfection single crystals; rectifier fabrication; and etching.

## Fulmer Research Institute

As has recently been announced the shares of Almin, Ltd., the parent company of Fulmer Research Institute, Ltd., have been acquired jointly by Imperial Chemical Industries, Ltd., and the Aluminum Co. of America. It is not expected that the change of ownership will affect the position of Fulmer as an independent institution for carrying out sponsored research, and the new owners of Almin, Ltd., wish it to be clearly understood that all work undertaken at Fulmer will remain strictly confidential to the sponsors.

General view of the 1,750 ton walking dragline recently installed at the Cowthick Ironstone quarry of Stewarts and Lloyds Minerals, Ltd. Made by Ransome and Rapier, Ltd., at a cost of £750,000, the machine is probably the largest in the world. The 303 ft. long jib, of welded tubular construction, was designed and built by Tubewrights, Ltd., a Stewarts and Lloyds subsidiary. In its working position the jib head is 185 ft. above the ground, and the 22 cu. yd. bucket takes a 33 ton "bite" at the overburden.



## Ultrasonic Inspection Conference

A CONFERENCE on the "Theory and Practice of Ultrasonic Inspection" is to be held at the Queen's Hotel, Cheltenham, during the period September 22nd to 24th, 1960. The arrangements are being made jointly by The Institute of Physics' Non-Destructive Testing Group, The Society of Non-Destructive Examination and The Non-Destructive Testing Society of Great Britain. Further details of the programme, and of hotel accommodation in Cheltenham, can be obtained from the Conference Secretary, Mr. I. M. Barnes, Materials Laboratory, de Havilland Propellers, Ltd., Hatfield, Herts.

## Research-Industry Link

THE Coil Spring Federation Research Organisation, which has now established its position as an active centre for research—culminating recently with the opening of new laboratories at Sheffield by Sir Harry Melville, K.C.B., F.R.S.,—launched a new service to industry at its annual conference at Llandudno, last month. Delegates were introduced to Mr. Henry Snow, a 42 year-old metallurgist, who has been appointed the organisation's first Industrial Liaison Officer. His job will be to improve the lines of communication between the laboratories and the factories. He will be "selling" research not only to the comparatively tiny spring-making industry itself—which employs only about 7,000 people—but to the many user-industries who are also members of the organisation. As a result of this appointment, the President of the C.S.F.R.O., Mr. R. Salter Bache, J.P., confidently expects that membership will increase, and that newly developed techniques will become even more widely used, so maintaining the British spring maker's reputation for quality and reliability.

## British Association Meeting

THE Annual Meeting of the British Association for the Advancement of Science will be held in Cardiff from August 31st to September 7th, 1960. The title of the address to be given at the inaugural meeting by this year's president, Sir George Thomson, F.R.S., will be "The Two Aspects of Science." In it, Sir George will consider on the one hand the effect of science on man's environment and, on the other, its effect on man's thoughts and sense of values.

A major innovation this year will be the devotion of the whole of Monday, September 5th, to a discussion and practical review of the vital issues arising out of the present world food situation. The main scientific programme will, as usual, be arranged in sections, and one of the topics for discussion will be of particular interest to South Wales, namely, the continuous casting of steel.

## Cambridge House

DURING the evenings of Wednesday, May 25th and Thursday, May 26th, a total of more than a hundred guests attended receptions held at "Cambridge House" (the new name for the head office and showrooms of the Cambridge Instrument Co., Ltd., at 13 Grosvenor Place, London). The receptions, held in the showroom and the new boardroom, were to celebrate the internal rebuilding and redecorating being carried out to modernise

the company's recently enlarged premises. The visitors were invited individually and entertained by members of the board of directors and the sales and publicity staff. Most of them were scientists and engineers representing industrial and research organisations interested in the company's products. Several foreign diplomatic delegations were also represented.

## Induction Heating Courses

Due to the extensive interest being shown in the induction heating courses organised by the Process Heating Division of Pye, Ltd., it has been decided to hold them at regular intervals. The next course will commence at 2.0 p.m. on Tuesday November 1st, and finish at 6.0 p.m. on Wednesday, November 2nd. Subjects to be covered again include the theory of induction heating, methods of application, the basis of coil design, hardening, annealing, tempering, brazing, soldering and special applications. The course itself is free but participants have to pay for their living accommodation which is normally arranged by the company. Further details are available from Mrs. E. Raeburn, Pye Process Heating, 28, James Street, Cambridge.

## Micro Reproduction of Theses

SOME time ago, Micro Methods, Ltd., of East Ardsley, Wakefield, Yorks., announced their intention of making available in micro form accounts of work carried out in the universities, often in the form of theses submitted for higher degrees. Two recently released items are of interest in the metallurgical field, namely, an account of work carried out in the Department of Metallurgy at Cambridge on the electrodeposition of tungsten-cobalt alloys; and a thesis submitted for the degree of Ph.D. in the University of Sheffield on the effect of coal-fired furnace atmospheres in the heating of steel.

## Magnesium Price Rise

MAGNESIUM ELEKTRON, LTD. recently announced an increase in price of commercial aluminium-containing magnesium alloys. Elektron "C" sand casting alloy is now 2s. 1d. per lb. delivered, as compared with 1s. 11½d. previously. The corresponding figures for AZ91X die casting alloy are 2s. 1½d. and 1s. 11½d. The new prices became effective on July 1st, 1960.

## Polarography Meeting

THE Polarographic Society announces that a meeting will be held at the Wolverhampton Technical College on Wednesday, September 21st, 1960, at 2.30 p.m. The subject will be "The Application of Polarography in Metallurgical Analysis." Further details concerning the meeting may be obtained from R. C. Rooney, Esq., British Cast Iron Research Association, Bordesley Hall, Alvechurch, Birmingham.

## Correction

### CHANGE OF ADDRESS

ON page 212 of our May issue, it was announced that the London Office of Uddeholm, Ltd. was to be moved to 124 Victoria Street, London, S.W.1. Unfortunately, these plans fell through, and readers are asked to note that the new London address of Uddeholm, Ltd., is now 78 Buckingham Gate, S.W.1. Tel. SULLivan 2741/2.

# RECENT DEVELOPMENTS

## MATERIALS : PROCESSES : EQUIPMENT

### Shell Core Blower

A NEW machine for producing shell cores from pre-coated resin sands has been introduced by the Foundry & Metallurgical Equipment Co., Ltd. This machine, the Reynolds shell core blower, performs up to 180 blows an hour, depending upon the type of core and the number of cores per box. The shells have only a fraction of the weight of solid cores and the saving in material, and the elimination of mixing operations, more than offset the higher cost of the resin-bonded sand. It is claimed that stronger cores are produced, special vents, supporting wires and driers are not required, and the cores are ready for use immediately without further stoving: storage life is considerably prolonged.

Operation of the machine is extremely simple. After closing the core box and raising the sand chamber to seal the core box entry, the cores are blown. The air is then exhausted from the sand chamber, the chamber lowered and the core box opened for removal of the cores. All these operations are completed in the right sequence with a single six-position control lever. A pneumatic vibrator, operated by a push button, empties sand from the cured shells and reduces wastage, and an automatic air blower nozzle and hose is fitted for clearing residual sand from working surfaces.

The core blower is enclosed in a floor standing cabinet which needs no fixing and which carries on the top two machined heads for holding the two halves of the core box. The height of the heads and the gap between them can be adjusted to suit the size of the core box. Mounted on these heads are the electrically heated plates to which the two halves of the core box are attached. The left hand plate is fixed and the other is moved by a heavy-duty pneumatic cylinder which therefore opens and closes the core box. Under the bed-plate is mounted the sand chamber, which is raised and lowered by an articulated linkage system operated by an air cylinder. The standard sand chamber has a capacity of 35 lb. but larger chambers are available. An attachment can be supplied to allow the use of three-part core boxes. The machine has an overall height of 4 ft. The cabinet is 3 ft. wide, 1 ft. 6 in. deep and 3 ft. high.

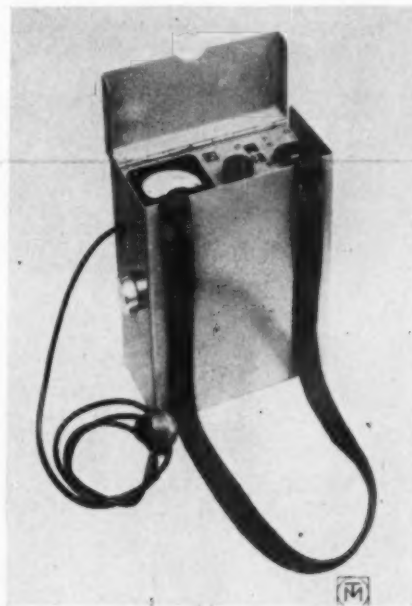
*Foundry & Metallurgical Equipment Co., Ltd., Netherby, Queens Road, Weybridge, Surrey.*

### Sorting Non-Ferrous Metals

AN instrument known as the Sortationer, which, it is claimed, is capable of differentiating between various aluminium alloys, magnesium alloys and copper alloys by indicating the difference in conductivity of a layer near the surface is being marketed by Townson & Mercer, Ltd. A special feature of the instrument is that the sensing head has been made relatively insensitive to distance, so that it will give a virtually constant reading, even if the head is not kept absolutely square on the surface, and even if the surface is uneven. Perhaps even

more important, it will give constant readings whether the surface is anodised, painted or both.

The principle of operation is that the sensing head contains a coil which may be considered as the primary of a transformer fed with a low radio frequency supply and the sample under investigation may be regarded as a single short-turn secondary winding. The inductance of the primary coil and its losses are affected by difference in electrical characteristics of the sample under test. Reductions in its inductance raise its tuned frequency, and increases in loss lower its efficiency. Both these effects are produced when a piece of non-ferrous metal is presented to it.



The circuit arrangement is such that the sensing-head coil is in the grid of an oscillatory valve circuit of which the anode coil is tuned to a slightly higher frequency. Increase of tuned frequency of the grid coil tends to bring the grid and anode coils into line, thereby increasing the grid/anode feedback until oscillation occurs, whereas the loss in efficiency of the grid coil delays this process, and by the combination of these two effects it has been found possible to arrange the circuit constants to make the instrument relatively insensitive to distance between the sample under test and the sensing head.

Like most instruments for this purpose, the sortationer has its limitations, arising from the fact that the conductivities of certain alloys can be made to vary over a very wide range by heat treatment. Works sometimes have supplies of say aluminium alloys and pure aluminium on which the marking is indistinct. If they are not heat

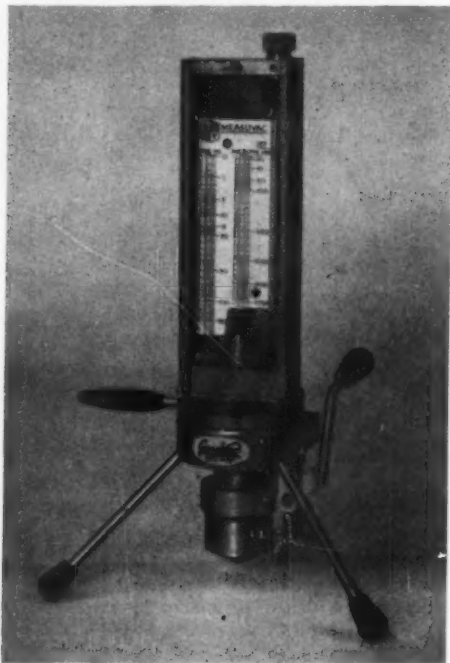
treated the instrument will instantly identify them. Likewise, it will function with magnesium and copper alloys, but must be reset for each basic metal. One could not take a stack of unknowns of mixed treated and untreated alloys and expect to differentiate with certainty, but the sortationer will identify pure aluminium and pure magnesium from all their alloys, and will sort the remainder into stacks which can usually be identified definitely by appearance or analysis.

Special applications include indicating which side of single sided Alclad is clad; differentiating between annealed and un-annealed Alclad; indicating heat damage to many heat treated alloys; indicating the degree of heat treatment of a particular alloy, acting as a "go, no-go" gauge; and finally, differentiating between tantalum and niobium, between gold and its alloys, and between silver and its alloys.

*Townson & Mercer, Ltd., Croydon, Surrey.*

### Measuvac McLeod Gauge

THE new Measuvac McLeod gauge has been designed to meet the increasing need for a general purpose vacuum gauge giving accurate and rapid pressure readings in all situations calling for a robustly constructed McLeod



gauge. It is claimed that for the first time a gauge of this type has been made of very small proportions covering a range of pressure hitherto not possible. The standard model covers the range from 150 mm. to 1 micron. This is achieved by the simple operation of depressing a lever which gives accurate readings simultaneously on two scales, one reading from 2 mm. to 150 mm., and the other from 1 micron to 2,000 microns.

On depressing the handle, the mercury rises in the three tubes and the rising level in the left-hand intake tube is adjusted to the set mark. With this held steady a

pressure reading is taken on the scale appropriate to the pressure range. Once the reading has been taken the operating lever is released and the mercury returns automatically to zero ready for the next reading. This eliminates any possibility of mercury being left in the tubes and resultant damage if the pressure should rise to atmospheric.

The construction of the gauge makes for ease of dismantling for repairs and cleaning which may be necessary from time to time.

*Genevac, Ltd., Pioneer Mills, Radcliffe, Manchester.*

### Heating Electrode

A NEW electrode, Thermees, for applying a rapid and concentrated heat to metal before welding, bending or straightening, is announced by English Electric. The electrode may be used on any standard metal and in any position. Heat can be thus applied in an exact spot and in normally inaccessible places without any special flame or induction heating equipment. Thermees is handled like a normal electrode and requires no special equipment or technique: it can be used on A.C. or D.C. welding plant. For best results the A.C. supply should have an open circuit voltage of 80-85 V. Temperature rise of the metal is regulated by the rate of travel and number of passes of the electrode. Any residual scale or oxide can be easily brushed off to leave the surface clean.

*The English Electric Co., Ltd., Marconi House, Strand, London, W.C.2.*

### Recording Hygrometer Alarm

SHAW MOISTURE METERS recently announced a new recording hygrometer alarm, incorporating the sensing element developed by Mr. J. L. Shaw. It records continuously the humidity of any atmosphere—hot or cold, dry or damp, under pressure or vacuum—and gives immediate warning of any change beyond specified limits. The instrument is transistorised and is fully stabilised for 150-260 V.; the sensitivity is 1 part in 10 million and the response time 1 second. The working temperature range is -50° C. to 150° C., and pressures up to 3,000 lb./sq. in. can be handled: deposits down to -150° C. can be measured. Trial before purchase is possible, in which case a rental is charged until payment is received or the instrument returned.

*Shaw Moisture Meters, Rawson Road, Westgate Bradford.*

### Premium Grade Carbide

WICKMAN'S Wimet Division has just announced the introduction of a new grade of carbide, designated Wimet XL35 and combining to an unusual extent the characteristics of wear resistance and toughness, which has been developed over the last few years for milling steel. Despite its high hardness of approximately 1,500 V.P.N., it is said to possess superior resistance to thermal cracking at the cutting edge, which has been achieved by the selection of correct grain structure. This makes it suitable for all face, slot and end milling operations on steel, operations which cause the greatest thermal shock because the cutting edge of the tool is heated rapidly to a high temperature whilst cutting, and suddenly cooled whilst passing through air. These tendencies are increased in operations such as slot milling, where the chip thickness tapers to zero and a rubbing action accentuates

these effects. It can also be used with advantage on other operations such as intermittent turning where thermal shock is encountered.

In a long testing programme it has been applied to crankshaft milling, milling slots of large and small rotors, and to a wide variety of die block milling, as well as to innumerable intermittent turning operations. In all of these, tool life has been considerably extended in comparison with other grades. Tips supplied in the new grade will carry a premium of 5%.

*Wickman, Ltd., Wimet Division, Coventry.*

### Silver Preparations

JOHNSON, MATTHEY & CO., LTD. recently announced that the research work carried out in collaboration with CIBA (A.R.L.), Ltd., has led to the development of two additions to the JMC range of thermo-setting silver preparations, namely FSP43, a surface-coating preparation for application by brushing; and FSP49, a conducting cement. Each is based on Araldite which contains silver in the form of flake, and is supplied as two separate components which are mixed together immediately before use. The mixed components will adhere to most materials capable of withstanding a curing temperature of 80° C., such as metals, glass, ceramics, graphite and many plastics.

FSP 43 produces a tougher and more adherent film than FSP 36—the earlier preparation—with a high degree of resistance to deterioration by water and organic solvents. It can also serve as a base for electroplating from many conventional acid baths. It cannot be soft soldered, nor should it be used as a conducting cement.

FSP 49 can be used to form a conducting bond between any materials capable of withstanding the 80° C. curing temperature. After curing it is extremely hard and wear resistant, has a high electrical conductivity, and is highly resistant to water and organic solvents.

*Johnson, Matthey & Co., Ltd., 73-83 Hatton Garden, London, E.C.1.*

### Combined Welder and Cutter

A COMBINED welding and cutting outfit now being introduced by British Industrial Gases, Ltd., will, it is claimed, bring substantial economies in gas consumption. The welding torch—the Economatic 50-2—will prove of particular value in production work or wherever there is continual operation. After lighting in the normal way, the welding flame is obtained simply by pressing a thumb lever which, when released, reduces the flame to a minute pilot light. A non-automatic version of the torch, Model 19-GMC, is also available. A feature of this precision-built equipment is that simply by unscrewing the mixer assembly and replacing it with a cutting head, the blowpipe is converted to a cutting torch.

Forward mounted controls are provided for easy adjustment, the knobs being suitably colour-coded, while the gas control valves are of the fine adjustment type. The cutting head—Model 36—is 7½ in. long and weighs 12 oz., complete with nozzle: it will cut sheet steel up to 3 in. thick. Of exceptional robustness, the small size and light weight of these torches makes them particularly useful where operators are obliged to work in confined or cramped positions.

Manufactured by British Industrial Gases by arrange-

ment with Harris Calorific Co., of Ohio, this equipment has already proved itself in America under a wide range of operating conditions.

*British Industrial Gases, Ltd., 700 Great Cambridge Road, Enfield, Middlesex.*

### Sealed-end Snaprib

SINCE Noral Snaprib Sheet was introduced some five years ago as a system of roofing and siding having an aesthetic appeal and also weathertightness deriving mainly from invisible fixing, it has constantly been improved by minor amendments in design. Now, an im-



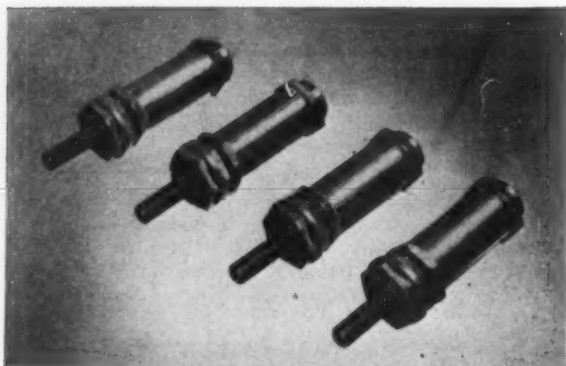
portant new development is announced, offering alternative treatments of eaves and ridge. Known as Sealed-end Snaprib, this new development incorporates an integral seal at eaves and ridge, or alternatively at eaves only. In each case the seal is produced by forming the end of the sheet, making the roof completely weathertight without the need of separate ridge or eaves fillers and permitting a shallow pitch. Moreover, it is even quicker to install than standard Snaprib. Once the roof sheets have been laid, a simple eaves flashing is hooked up into a slot formed by the folded end of the sheet and secured to the vertical wall; similarly a two-part adjustable ridge assembly is readily and securely clipped into place on the flanges of the roof sheets. The seal at the eaves end is particularly advantageous, for it improves the eaves line, giving it a pleasing firmness and solidity, and it increases even further the rigidity against wind load. It may also be preferred for siding, the sealed end giving a better finish to the base of the wall.

Full details of Noral Sealed-end Snaprib are given in a four-page folder of that name, which includes fixing instructions and also a summary of the Snaprib system.

*Northern Aluminium Co., Ltd., Banbury, Oxfordshire.*

### Pneumatic Cylinders

To meet the increasing demand for a robust, small bore cylinder of light construction, Baldwin Industrial Controls have introduced three new basic cylinders to their range. Bore sizes are ¾, 1 and 1½ in. with strokes ranging from 1 in. in the ¾ in. bore size to 10 in. in the 1½ in. bore. Cylinders can be either double-acting or single-acting with spring return. These cylinders have been designed



primarily for light holding, clamping, or similar jobs where small physical size combined with rugged construction are first considerations. Maximum air pressure is 150 lb./sq. in.

*Baldwin Industrial Controls, Ltd., Dartford, Kent.*

### New Transistor Techniques

A NEW way of using a symmetrical transistor—as a chopper—has been developed by Smiths Aviation Division, principally for use with thermocouples. The company also visualises the use of its transistor chopper technique in strain-gauge work. Earlier objections to transistor choppers for field work—such as the need for accurate setting-up beforehand to obtain a low and constant rate of drift with temperature change—are said to be largely overcome. With the new method, setting-up is obviated or, for certain application, reduced to a minimum, and performance can be guaranteed from a standard batch of transistors. Smiths claim a drift rate of better than  $1.5 \mu\text{V}/^{\circ}\text{C}$ . without selection from a batch or setting-up: with limited setting-up, results are better than  $1.0 \mu\text{V}/^{\circ}\text{C}$ . This claim holds good over a wide temperature range from  $-40^{\circ}\text{C}$ . to  $+100^{\circ}\text{C}$ . using silicon transistors.

The new technique has changed the use of transistor choppers from circuits suitable for use mainly in laboratory work, to circuits available for use in robust instruments capable of withstanding the rough conditions of general work. Results so far have been obtained on batches of experimental symmetrical silicon-alloy transistors which are available in limited quantities from Semiconductors, Ltd.

Summarising, the four advantages claimed for the Smiths application of symmetrical transistor choppers are:—

- (1) No setting-up required. Drift rates with temperature changes are low and constant with standard batches of transistors.
- (2) Small size. The transistor chopper circuit, which includes two transistors, four resistors and one transformer, is about one quarter of the size of a mechanical chopper.
- (3) Weight reduction, as compared with a mechanical chopper.
- (4) Robustness. Will withstand the normal vicissitudes of field use.

*Smiths Aviation Division, Kelvin House, Wembley Park Drive, Wembley, Middlesex.*

### Process Timer

ELCONTROL, LTD., have recently introduced a new high accuracy electronic process timer, the Type TRU4. While basically similar to the standard TRU range, the circuit has been designed to give exceptionally high repetitive accuracy, i.e. better than  $\pm 0.1\%$  under normal supply conditions. Elcontrol state that this timer was developed particularly for a filling machine manufacturer who found that excessive mains voltage fluctuations caused by switching of heavy loads prevented standard electronic timers from achieving their normal accuracy, with consequent wastage on the filling plant dealing with a costly product. It was found that, even with an exceptionally high mains voltage swing of  $\pm 25\%$ , the repetitive accuracy of the TRU4 was within  $\pm 0.25\%$ . The unit is now available for general use: it can also be supplied as a cyclic timer where continuous operation is required.

*Elcontrol, Ltd., Willbury Way, Hitchin, Herts.*

### Transistorised Temperature Controller

A NEW fully transistorised printed circuit amplifier-relay for use as a stable, sensitive, temperature controller, has been introduced by Honeywell Controls, Ltd. With the appropriate thermistor temperature sensor, the R7079/7081 Versa-Tran can be used for control in the range of  $60^{\circ}$  to  $+500^{\circ}\text{F}$ . with a differential of  $1.5^{\circ}\text{F}$ . or  $0.3^{\circ}\text{F}$ ., depending on the model. Control is very stable and errors due to ambient temperature conditions are easily compensated for by means of a calibration dial.

Wiring between sensing element and relay need not be shielded; the bridge presents no capacity balance problems; ordinary 18 s.w.g. two-conductor insulated cable will suffice. The control, which incorporates the load relay, can be used up to 300 ft. from the thermistor and operates from the 240 V. 50 c./s. supply.

Versa-Tran controllers are available for surface mounting, flush mounting, or mounting in most electrical enclosures. For full details, specification S1010-6 is available on request.

*Honeywell Controls Ltd., Ruislip Road East, Greenford, Middlesex.*

### Silicone Grease M.494

A NEW silicone grease, M.494, has been added to the rapidly growing range of I.C.I. Nobel Division silicone products. The outstanding electrical qualities of M.494, coupled with the silicone characteristic of intense water-repellency, give it exceptional efficiency as a sealing agent for electrical equipment, and as a general agent to protect surfaces against moisture. Technically and economically M.494 has proved its worth in many specialised and varied applications which include: protection of insulation from corona discharge; sealing and potting grease in electronic equipment; lubricant for electric cable prior to its being drawn through conduits, harness, etc; release agent in moulding and casting operations; packing grease for glands and for impregnating asbestos packing to prevent sticking of joints; glass stop-clock lubricant; lubricant for preventing sticking of screw threads, e.g. with electric fittings located outdoors and vacuum sealing grease.

*Imperial Chemical Industries, Ltd., Nobel Division, Silicones Department, Stevenston, Ayrshire.*

# CURRENT LITERATURE

## Trade Publications

JOHNSON, MATTHEY & Co., LTD., announce that they have adopted the name Silver Star to cover their entire range of precision silvered mica capacitors. All the components produced in the future will bear a silver star as a final inspection mark, indicating that the capacitor has undergone four final inspection tests for capacitance, power factor, proof voltage and insulating resistance. The range covers a wide variety of sizes and finishes and all capacitance values up to  $0.25\mu\text{F}$ . It includes the new type H capacitors that have been developed for operation at temperatures up to  $250^\circ\text{C}$ . Information on Silver Star capacitors is available in an entirely new series of data sheets. These data sheets, enclosed in a binder (publication 1460), together with a descriptive booklet (publication 1461), are available free on request from the company's head office at 73-83 Hatton Garden, London, E.C.1.

THE Bureau voor Handelsinlichtingen (Buvoha) was set up in 1903 by the Netherlands Society for Industry and Trade, and its object is to further the interests of Netherlands industry, trade, agriculture, fisheries, shipping, etc., by supplying them with practical information. One of its activities is the annual publication of "Buvoha Trade Letter," the 1960 issue of which has recently appeared. It contains addresses of industrial and commercial firms in the Netherlands interested in trade relations with firms abroad, and copies may be obtained from the Bureau at Amsterdam-C. (Holland), 16 Oudelrugsteeg.

"THERE'S nothing like the Purple Peeper" is the colourful title of a new Honeywell Controls publication printed on paper to match. The reason for this description of the new Honeywell Ultra-Vision flame detector is that it is designed to sense only ultra-violet radiation. Among the advantages claimed for this device are the following: it will not respond to simulated flame conditions; it positively discriminates between flame and hot refractory; it stops fuel delivery instantly on flame failure; it provides flame protection for every type of fuel; and it provides protection for the most difficult applications, such as exothermic gas generators.

NOT without a certain amount of justification, the introduction to the Summer number of *Copper*, the Copper Development Association's quarterly publication, suggests that the subject matter in this issue is almost as all-embracing as Lewis Carroll's agenda for discussion by the Walrus and the Carpenter. Certainly the "ships" mentioned by Carroll are there in an article dealing with the vital role played by copper alloys in marine engineering; and the "cabbages", whilst not actually named, are just around the corner in the feature on cooking with copper utensils. The christening of the last steam locomotive to be built for British Railways provides a reminder of copper's part in the past, present and future development of railway engineering. Other topics featured include the melting and casting of copper alloys, power for the Copperbelt, copper roofing and modern architecture, and a solar water heater for domestic purposes.

As far as efficiency is concerned, there is no doubt that the battle of the fuels should be to the benefit of the user, as each industry strives to provide the best heating unit for a particular purpose. In the July issue of *Edgar Allen News*, pride of place is given to an article on the development and application of a high intensity oil combustion furnace by David Etchells & Son, Ltd., and David Etchells (Furnaces) Ltd. Other features include an extract for the revised edition of Gregory and Simon's book on the heat treatment of steel, the first part of an article on the metal arc welding of stainless steel, and an account of the use of Edgar Allen steels for plastic dies in Australia.

THE Summer issue of *The Brightside News* features a description of the new bar and rod mill installed at the works of Samuel Fox and Co., Ltd., of Stockbridge, a branch of the United Steel Cos., Ltd. The mill rolls high carbon, alloy and stainless steel, and the installation includes a special bar heat treatment plant. This issue also contains an item on the Newhall machine shop, where Brightside rolls are machined for customers in many industries whose activities include the processing of steel, rubber, plastics and paper.

ALTHOUGH zirconium was identified over 150 years ago, it was not until 1945 that pure ductile material could be prepared and consolidated in commercially useful quantities. With the rapid development of nuclear engineering, zirconium, combining low neutron absorption with high mechanical strength at room and elevated temperatures and with outstanding corrosion resistance, has become a very important metal. A booklet entitled "I.C.I. Wrought Zirconium," recently published by I.C.I. Metals Division, contains data on the mechanical and physical properties of I.C.I. zirconium and zirconium alloys and the forms in which they are produced. Information on the associated metal, hafnium, is also given.

THE refractory problems facing steel works engineers are many and varied, and Morgan Refractories, Ltd., have recently issued a leaflet illustrating the use of their Tri-Mor refractories in solving many of them. This range of high quality refractories includes both pre-fired firebricks and monolithic materials such as castables and mouldables. The sections of the plant detailed include blast furnaces, soaking pits, reheating furnaces, forging furnaces, heat treatment furnaces, strip and coil annealing furnaces, and burner openings of reheating and annealing furnaces.

THE data book published by Henry Wiggin & Co., Ltd., on the Nimonic heat-resisting alloys has recently been revised. The contents cover the complete properties of the alloys currently manufactured in the Nimonic series. (These alloys were originally designed for use in the aircraft gas turbine engine, but now have many applications in other industries. The publication includes tables on mechanical and physical properties, creep characteristics, and fatigue and impact properties. A series of diagrams give detailed data on creep properties in a form convenient to the designer. The extensive programme of testing which has been followed is reflected in the long-time creep curves presented in this publication and in some specimens, tests have been continued for nearly 46,000 hours.

A NEW edition of Dry Pneumatics, publication No. 709, issued recently by AEI-Birlec, Ltd., includes details of an entirely new range of Birlec refrigeration dryers designed to meet the needs of users requiring compressed air at dewpoints down only to freezing point. Compared with adsorption drying, not only is there a saving in capital cost but operating expenses are considerably reduced. In particular, power consumption is generally halved. Automatic defrosting equipment is available for the more stringent applications.

A NEW publication, "Nimocast Heat-Resisting Alloys," has been published by Henry Wiggin & Co., Ltd. The Nimocast series of cast alloys which combine high-temperature strength and scaling resistance, are similar to, and in some instances identical in composition with the company's Nimonic series of wrought alloys. The major part of the publication is devoted to physical and mechanical properties, which are recorded in tabular form. The tables include the physical properties, standard heat treatment, oxidation data, and recommended pouring temperatures. Also included are a series of stress rupture graphs covering all the Nimocast alloys, in some instances tests have been carried out for over 3,000 hours. A chapter entitled "Further Developments" deals with the company's progressive research programme and refers to work on three new casting materials offering improved properties.

THE choice of a vacuum for sintering may be based either on its function as a "protective atmosphere" or on the need for low pressure to achieve a desired result. Both aspects are discussed in an interesting article on vacuum sintering which appears in the latest issue of *Murex Review* (Vol. 2, No. 22), in which reference is made to the application of the process to the sintering of (a) titanium and titanium hydride powders, (b) hard metals, and (c) niobium. The issue also features an article on the effect of molten metals on stressed solid metals, which takes the form of a summary of the published work on the embrittlement of solid metals by lower melting point liquid metals and discusses some of the theories for this type of failure.

THE new and revised 70-page catalogue of the Sheffield Wire Rope Co., Ltd., a member of the Firth Cleveland Group, lists the company's ropes in accordance with the revised British Standards, together with a wealth of introductory notes. These cover, in text and illustration, such subjects as the lays of wire rope, preformed wire rope, the handling and care of ropes, recommended pulley diameters, etc. The company produces wire rope for the mining, engineering and marine industries. The catalogue is available on request from the Sheffield Wire Rope Co., Ltd., Darnall, Sheffield 9.

PROPERTIES of two new stainless steel-bonded carbides are tabulated in Bulletin 60, available from Sintercast Division of Chromalloy Corporation, Yonkers 2, N.Y., U.S.A. Called Ferro-Tie S, these compositions are formulated for applications requiring unusual corrosion resistance or strength at high temperatures, as well as abrasion resistance and hardness. Because these carbides are machinable, tools and components may be fabricated from blanks using conventional equipment, rather than diamond grinding wheels. The resulting parts combine stainless steel's heat and corrosion resistance with the ultra-hardness of titanium carbide. The new bulletin describes physical properties of both

grades of Ferro-Tie S carbides, having a Rockwell C hardness of either 45 or 55.

HADFIELD, LTD., have recently issued a new leaflet (No. 546), dealing with Hecla 174. This is a chromium-molybdenum-vanadium steel whose outstanding feature is the ability to withstand alternate heating and cooling without the occurrence of the crazing associated with heat shock. Typical applications include extrusion mandrels, hot forging dies, extrusion dies, die casting dies, etc. Particulars are given of composition, heat treatment and physical properties.

THE latest edition of the well-known Pye scientific instrument catalogue describes several important new developments which will interest those concerned with scientific research or industrial production testing and process control. The important new developments mentioned here include a stabilised power supply unit, a precision decade potentiometer, a pH extension meter, an autotitrator-controller, apparatus for the automatic determination of sulphur content, and an argon chromatograph with new accessories. Catalogue "N" is distinguished by its orange cover, and it supersedes all previous additions which should now be destroyed. Copies can be obtained from W. G. Pye & Co., Ltd., Granta Works, P.O. Box 60, Cambridge, England.

NEGRETTI & ZAMBRA have recently issued three new publications. These are: (1) R30/2E, dealing with electric switch and contact automatic controllers and alarm mechanisms; (2) A/19, integrating indicator (Type I.R.) for use with N & Z aircraft fuel flowmeter; and (3) F25/S, Spanish version of the general catalogue: this is the sixteenth version of this catalogue. Copies of these publications are available on application from Negretti & Zambra, Ltd., 122 Regent Street, London W.1.

THE ASSOCIATION OF LIGHT ALLOY REFINERS AND SMELTERS, LTD., has recently published a revised edition of its mounted data sheet to replace the 1955 issue. The amendments mainly concern the "Related Specifications" section, and are the result of the revision of the B.S. "L" series of aircraft standards and the transfer of four D.T.D. specifications to the "L" series. One of these, the familiar D.T.D.424A, will in future be known as B.S. L79: the B.S.1490 "LM" numbers remain unchanged. Copies of the data sheet may be obtained from F. H. Smith, technical officer of the Association, at 3 Albemarle Street, London, W.1.

## Books Received

"A History of Metals." Vols. I and II. By L. Aitchison. 690 pp. including 262 illustrations and 48 tables. London, 1960. Macdonald & Evans, Ltd. 168s. for the two volumes.

"Aircraft and Missile Design and Maintenance Handbook." By C. A. Overbey. 369 pp. inc. index. New York and London, 1960. \$9.75 or 68s.

"The Manufacture of Iron and Steel." Volume III. "Steelworks Fuels, Refractories and Instruments." By G. R. Bashforth. 246 pp. inc. index. London, 1960. Chapman & Hall, Ltd. 35s. net.

"Mechanical Properties of Intermetallic Compounds." Edited by J. H. Westbrook. 435 pp., inc. author, compound and subject indexes. New York and London, 1960. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 76s. net.



During wartime, gas masks were issued for filtering out poisonous and harmful constituents from air in the event of a gas attack. Birlec adsorption dryers are used for removing water vapour from process gases employed in modern manufacturing techniques. For process protection in the metallurgical, chemical and electrical industries, dew-points below  $-40^{\circ}\text{C}$ . are frequently required. Standard Birlec dryers are available for such applications and specialised equipment can be built for obtaining dew-points down to  $-100^{\circ}\text{C}$ . Users of one or more of the gases listed alongside are invited to write to Birlec for a copy of Publication No. 82/4.



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METALLURGIA, July, 1960

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# LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

JULY, 1960

Vol. LXII, No. 369

## The Spectrophotometric Determination of Cobalt in Copper Alloys

By G. Lindley

Works Chemical Laboratory, English Electric Co., Ltd., Bradford

*A simple method has been developed for the determination of cobalt in copper alloys. The copper is separated electrolytically prior to converting the cobalt to cobaltous chloride by means of hydrochloric acid. The absorption of this solution is then measured spectrophotometrically at a wavelength of 625 mμ. The effects of other elements have also been investigated.*

IN many analytical methods, the simpler types of reaction appear to be neglected in favour of more complex procedures, which, in many cases show little or no resultant advantages. During investigations on copper-cobalt alloys, it became necessary to determine cobalt contents. A review of methods available revealed that closely controlled reaction conditions are generally necessary. For this work, it was considered that a much

simpler method was desirable, and the possibility of employing measurement of the blue colour of cobaltous chloride in strong acid solution was investigated.

Although some work has been published on the spectrophotometry of metal chlorides and chloride complexes,<sup>1-6</sup> little direct application of this has been made in analysis. In a few cases, measurement of the pink colour of cobaltous sulphate has been used.<sup>7,8</sup> It was decided to use the chloride system for this work, since previous experiments in this laboratory had shown that this would offer several advantages, including greater sensitivity.

When in solution, cobaltous chloride can exhibit a range of colours from pink to blue, depending upon many conditions, such as use of aqueous solvents, presence of other salts, temperature, acidity, etc. Since the blue form has been reported<sup>9,10</sup> as being about ninety times more sensitive than the red form, conditions of high acidity were chosen to favour this formation. This blue colour is probably due to the cobalt being present as a complex anion with the halide, whereas the pink colour is probably due to a simple cobaltous cation.

### Absorption Spectra

In the proposed procedure, copper was to be separated electrolytically. It was decided to investigate any interference which might be caused by the presence of residual copper in the electrolyte due to any inefficient separation. It was also decided to assess the order of interference which might be expected from the presence of other elements in the alloys, which would remain in the electrolyte, and which might absorb in the wavelength region of the cobaltous chloride. As a preliminary investigation absorption spectra were plotted, using a Unicam S.P.600 spectrophotometer, of the chlorides of cobalt, chromium, nickel, copper and ferric iron in strong hydrochloric acid solution. The spectra obtained are shown, on a reduced scale, in Fig. 1. The wavelengths of peak absorption and corresponding approximate molecular extinction coefficients are shown in Table I.

These results indicated that the cobaltous chloride

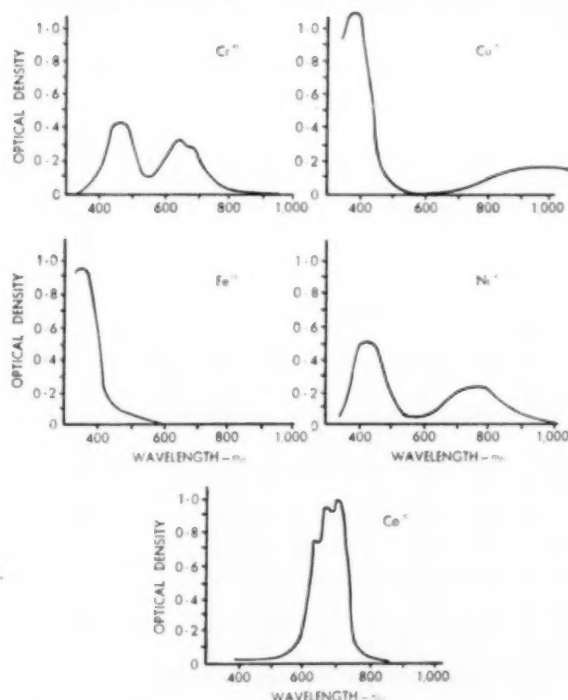


Fig. 1.—Absorption spectra in concentrated hydrochloric acid solution.

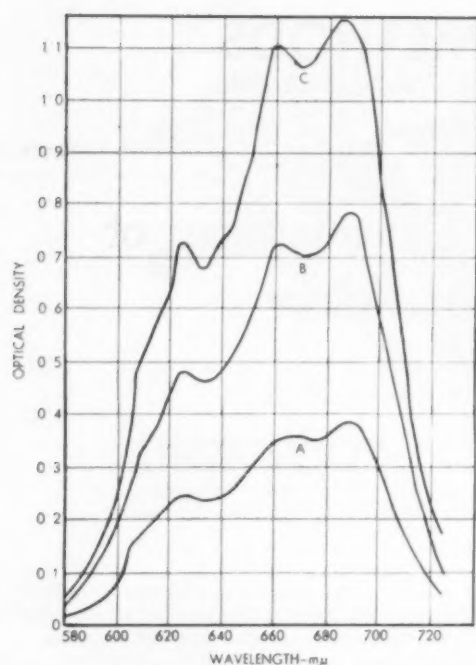


Fig. 2.—Absorption spectra of cobaltous chloride: (A) 0.04 mg. Co/ml.; (B) 0.08 mg. Co/ml.; (C) 0.12 mg. Co/ml.

absorption, at any one of its three peak wavelengths, would be sufficiently sensitive for this determination. The only elements likely to interfere, due to coloured ions, in the cobalt wave-band are nickel and chromium. By comparison of the molecular extinction coefficients, however, appreciable amounts of these two elements would be needed to cause such interference.

A detailed plot was next made, in concentrated hydrochloric acid solution, of different concentrations of cobalt. The spectra thus obtained are shown in Fig. 2. For each peak wave-length, the relation between optical density and cobalt concentration was found to be linear, and the system thus obeys Beer's Law.

#### Effect of Acid Concentration

Since acidity is the major factor governing the production of the blue compound, a standard cobalt solution was treated with hydrochloric acid solution of different concentrations in order to investigate the effect of acidity. These solutions were diluted to a standard volume, and optical density readings were taken at the three peak wavelengths for the cobaltous chloride. The results obtained are plotted in Fig. 3, from which it will be seen that at a concentration of about 200 g. HCl/litre a strong intensification in colour commences. This is the

point at which formation of the blue compound begins, and this proceeds rapidly as the acidity is increased to about 380 g. HCl/litre. Beyond this point the effect of acidity is somewhat less pronounced. These results indicate that acidity must be controlled and that maximum sensitivity occurs at the highest acid concentration. Consequently, it was decided to investigate the effect of acidity at these high concentrations. Optical density measurements were made of solutions containing hydrochloric acid of various concentrations between 387 and 430 g./litre: the results are plotted in Fig. 4. In this range, the effect of variation in acid concentration is not critical, the effect being slightly more pronounced at the higher wavelengths. Thus, a variation of  $\pm 10$  g. HCl/litre in solution results in an error in density measurement of  $\pm 0.007$  units at 625  $m\mu$  and  $\pm 0.010$  units at 690  $m\mu$ . For the range of cobalt concentration to be covered, these errors are negligible and can further be reduced by preparation of the hydrochloric acid to a given specific gravity. In order to avoid any difficulties due to variation in the stock acid (S.G. approx. 1.18), it was decided to adjust the latter, by addition of water to S.G. 1.175 at 20°C. This corresponds to an acidity of 414 g. HCl/litre.<sup>11</sup>

#### Effect of Copper

For the analysis of copper alloys, the copper is separated electrolytically from dilute acid solution, this operation also providing an accurate determination of the copper content. The cobalt is not deposited under these conditions. For cases where electrodeposition might be required to provide a separation only, it was decided to determine the degree of separation required, i.e. the amount of residual copper which could be tolerated in the electrolyte.

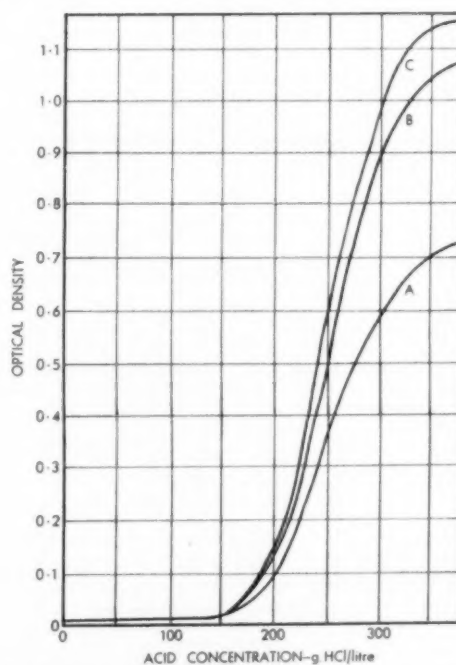


Fig. 3.—Effect of acid concentration with 1 cm. cells and 0.12 mg. Co/ml.: (A) 625  $m\mu$ ; (B) 660  $m\mu$ ; (C) 690  $m\mu$ .

TABLE I.—ABSORPTION MAXIMA ACID CHLORIDE SOLUTIONS.

	$m\mu$	E	$m\mu$	E	$m\mu$	E
Cobalt II . . . . .	690	572	660	531	625	354
Copper II . . . . .	385	1,360	960	104	—	—
Nickel II . . . . .	410	8	760	8	—	—
Chromium III . . . . .	460	27	650	21	—	—
Iron III . . . . .	300	2,940	—	—	—	—

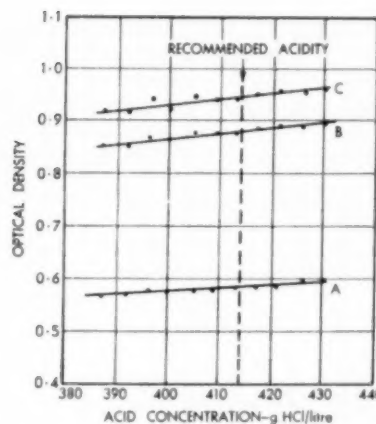
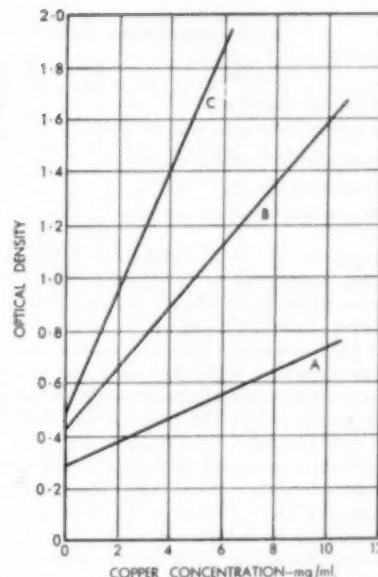


Fig. 4.—Effect of high acid concentrations with 1 cm. cells and 0.12 mg. Co/ml.: (A) 625  $m\mu$ ; (B) 660  $m\mu$ ; (C) 690  $m\mu$ .

Fig. 5.—Interference due to copper with 1 cm. cells and 0.05 mg. Co/ml.: (A) 625  $m\mu$ ; (B) 660  $m\mu$ ; (C) 690  $m\mu$ .



Standard cobalt solutions were prepared containing varying amounts of cupric chloride. These mixtures were diluted to a fixed volume and in all cases the final acid concentration was 414 g./litre. Optical density readings were made at the three peak wavelengths for cobalt, the results obtained being plotted in Fig. 5. It is seen that copper interferes at all wavelengths, the interference being least at 625  $m\mu$ . In all cases a linear relation exists between optical density and copper concentration. The nature of the copper interference is illustrated in Fig. 6, where absorption spectra are plotted of the cobaltous-copper chloride mixtures.

In order to cover the required cobalt contents in the alloys to be analysed, the results obtained above indicate that a sample weight of 0.2 g. in a final volume of 20 ml. would be suitable. Using this as a basis, a closer

investigation of copper interference was made with cobaltous-cupric chloride mixtures. Copper contents up to 2.5% were investigated, this limit being equivalent to 97.5% removal of copper by electrolysis. The results obtained showed that each 1% residual copper would produce an error of 0.004, 0.012 and 0.023 optical density units at 625, 660 and 690  $m\mu$  respectively. Consequently, it was decided to use the 625  $m\mu$  wavelength to minimise copper interference, and, provided the electrolytic separation of the copper is not less than about 98–99% efficient, negligible errors will be involved.

#### Effects of Other Elements

Although the method is for application to copper-cobalt alloys, it was decided to investigate the effect of other elements in order to extend the method to a wider range of alloys and to other samples such as corrosion products, etc.

Standard metal chloride solutions were added to a solution containing 0.1 mg. Co/ml. All solutions were

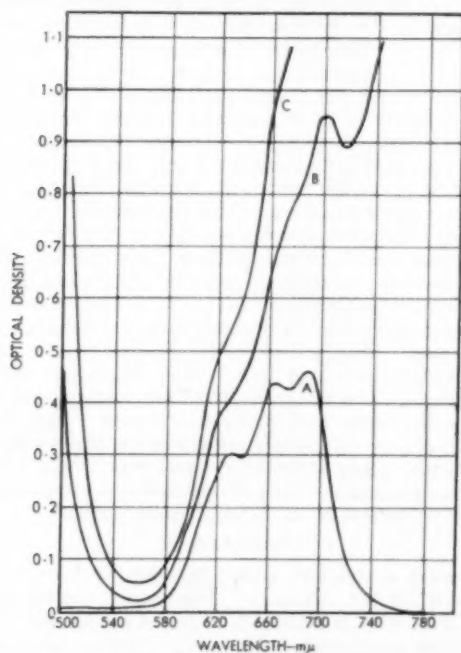


Fig. 6.—Absorption spectra showing copper interference: (A) no copper; (B) 2 mg. Cu/ml.; (C) 5 mg. Cu/ml.

TABLE II.—EFFECT OF OTHER ELEMENTS  
Total volume: 20 ml.; cobalt content: 0.1 mg./ml. = 1% Co on an assumed 0.2 g. sample.

Element	Concentration (mg./ml.)	Amount present (%) <sup>a</sup>	Optical Density Reading
Al III	0.5	5	0.608
Sb V	0.5	5	0.601
As V	0.2	2	0.609
Bi III	0.2	2	0.609
Cd II	1.0	10	0.608
Fe III	0.5	5	0.601
Mg II	0.2	2	0.607
Mn II	0.5	5	0.615
P†	0.5	5	0.601
Be II	0.5	5	0.601
Pb II	1.0	10	0.607
Cr III	0.2	2	0.672
Cr III	0.5	5	0.706
Ni II	0.2	2	0.617
Ni II	0.5	5	0.650
Ni II	1.0	10	0.680
Zn II	4.0	40	0.618

<sup>a</sup> Calculated for a 0.2 g. sample.

† Added as ortho-phosphoric acid.

TABLE III.—APPLICATION OF METHOD TO A BRONZE  
(Sample: B.C.S. Bronze A; cobalt added: 0.20%)

Sample	Optical Density Reading	Cobalt Found (%)
Bronze with no added cobalt	0.005	0.002 (approx.)
Bronze with 0.20% added cobalt	0.480	0.20
Bronze with 0.20% added cobalt	0.480	0.20
Bronze with 0.20% added cobalt	0.480	0.20
Cobalt solution with no bronze present	0.475	0.20

adjusted to a final volume of 20 ml., the acid concentration being 414 g. HCl/litre. Optical density readings were made at 625  $m\mu$  in a 1 cm. cell, the results obtained being shown in Table II.

It is apparent that the only elements in the common copper alloys which are likely to interfere, giving rise to high results, are chromium, nickel and high zinc contents. In order to test the effect of tin, a B.C.S. Bronze A. was "synthesised" to contain 0.20% Co. This sample was attacked with concentrated nitric acid and the precipitated metastannic acid was separated by filtration, using dilute nitric acid washing. The filtrate was adjusted to suitable acidity and the copper separated electrolytically. The cobalt in the electrolyte was then determined as in the recommended procedure described below. The results obtained, shown in Table III, indicate that any tin present can be separated as metastannic acid without any adverse effects on the results.

#### Calibration

Calibration was carried out as described below, the results obtained being shown in Fig. 7. Calibration is linear, and the slopes of the lines obtained using 1 cm. and 4 cm. cells are in the ratio 1:3.99 thus indicating very close conformity to Beer's Law. Further extension to cover other cobalt ranges can be obtained by using other cell widths or different final volumes of solutions.

#### Accuracy

Since no standards containing cobalt were available, accuracy was checked by analysing "synthetic" copper-cobalt standards. The results obtained are shown in Table IV, these having been obtained by different operators analysing random batches.

#### Recommended Procedure

As a result of the above work, the following method is recommended.

**Reagent**—Hydrochloric acid, 414 g. HCl./litre.

Adjust concentrated hydrochloric acid (S.G. 1.18) to S.G. 1.175 by addition of water. Check at 20° C. with hydrometer.

**Spectrophotometer**—Unicam S.P. 600, or other instrument giving suitable wavelength selection of 625  $m\mu$ .

For cobalt up to 0.04 mg./ml. (i.e. up to 0.4% Co on 0.2 g. sample in 20 ml.) use 4 cm. cells.

For cobalt from 0.04 to 0.15 mg./ml. (i.e. 0.4%—1.5% Co on 0.2 g. sample in 20 ml.) use 1 cm. cells.

TABLE V.—ACCURACY ON "SYNTHETIC" COPPER-COBALT MIXTURES

Cobalt Added (%)	Cobalt Found (%)						
0.10	0.11	0.11	0.12	0.11	0.13	0.11	0.13
0.50	0.53	0.50	0.53	0.52	0.49	0.50	0.51
1.00	1.01	1.00	1.00	1.02	—	—	—
1.20	1.23	1.17	1.21	1.21	—	—	—

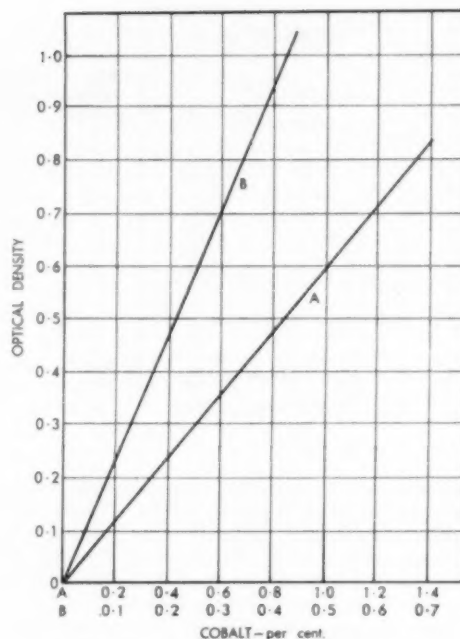


Fig. 7.—Calibration curves at 625  $m\mu$ : (A) 1 cm. cells; (B) 4 cm. cells.

#### Procedure

Transfer 0.2 g. sample to a 100 ml. tall beaker. Dissolve in a minimum amount of concentrated nitric acid (S.G. 1.42). Evaporate almost to dryness to remove excess acid, then add about 50 ml. of water. Boil to dissolve salts, and if any metastannic acid separates, digest hot for about half an hour and then filter through a Whatman No. 40 filter paper, washing with hot 2% nitric acid. Electrolyse the solution with platinum electrodes to separate the copper. When deposition is judged to be complete, add a little water to the electrolyte, thus raising the level of the latter to cover a fresh surface of the cathode. Continue electrolysis for a further 10–15 mins. in order to determine if any further deposition occurs on the newly immersed part of the cathode. After ensuring correct removal of copper, remove the electrolyte from the electrodes without switching off the current and rinse the electrodes with a little distilled water. Evaporate the solution to dryness. Add a few drops of concentrated hydrochloric acid (S.G. 1.18) to the residue and again evaporate to dryness to ensure removal of the nitric acid. Finally dissolve the residue in a few ml. of cold hydrochloric acid S.G. 1.175. Wash the resulting solution into a 20 ml. graduated flask, washing and diluting to the mark with hydrochloric acid. Measure the optical density on the spectrophotometer at a wavelength of 625  $m\mu$ , using hydrochloric acid S.G. 1.175 as compensating solution. Convert optical density to percentage cobalt by reference to the calibration curve.

#### Calibration

Prepare a standard cobalt solution as follows. Dissolve 0.1 g. of Matthey "Speepure" cobalt sponge (No. J.M. 870) in about 10–20 ml. of aqua regia: when dissolved evaporate to dryness. Moisten the residue with concentrated hydrochloric acid (S.G. 1.18) and evaporate to dryness. Dissolve the residue in cold

hydrochloric acid S.G. 1.175 and dilute with this acid to 500 ml. in a graduated flask.

1 ml. = 0.2 mg. Co. = 0.1% Co on 0.2 g. sample.

For calibration, add the cobalt solution by burette to 20 ml. graduated flask. Use 1, 2, 3, 4 ml. for the low cobalt range up to 0.4% and use 3, 6, 9, 12, 15 ml. for the higher cobalt range up to 1.5%. Measure the optical densities of these solutions at 625 m $\mu$ . in 4 cm. cells for the low range and 1 cm. cells for the high range, using hydrochloric acid, S.G. 1.175, as compensating solution. The calibration curves should be linear, passing through the origin.

#### Acknowledgment

The author wishes to thank the English Electric Co., Ltd for permission to publish this paper.

#### REFERENCES

- 1 Dawson, L. B. and Chandet, J. H., *J. Chem. Phys.*, 1951, **19**, 771.
- 2 Deness, M. A. and Rogers, L. B., *Anal. Chim. Acta.*, 1952, **6**, 534.
- 3 Friedman, H. L., *J. Amer. Chem. Soc.*, 1952, **74**, 5.
- 4 Rüttner, C., *Z. anorg. Chem.*, 1914, **96**, 341.
- 5 Heinz, W., *Z. anal. Chem.*, 1929, **78**, 427.
- 6 Finsl, H., *Arch. Eisenhütte*, 1940, **13**, 333.
- 7 Gagnon, J., *Chemist Analyst*, 1954, **43**, 15.
- 8 Foulke, D. G., *Metal Finishing*, 1948, October, 58.
- 9 Rohde, L. and Vogt, E., *Z. Phys. Chem.*, 1932, **B15**, 353.
- 10 Howell, D. R. and Jackson A., *J. Chem. Soc.*, 1926, 1268.
- 11 R.S. 976: 1957. Density Composition Table for Aqueous Solutions of Hydrochloric Acid.

## Detection of Traces of Oxygen in Gases The Methylene Blue Method

By P. S. Davis

*Australian Atomic Energy Commission, Lucas Heights, N.S.W.*

*A simple method for the detection of traces of oxygen in gas streams is described. The method is based on the colour change which occurs when leuco-methylene blue is oxidised to methylene blue. Suggested uses of the method are in argon-arc welding and glove-box work where oxygen must be excluded.*

WHILE such instruments as the Hersch galvanic oxygen meter<sup>1</sup> and the mass spectrometer<sup>2</sup> are used for the accurate determination of traces of oxygen in gases, there is a need for a simple, inexpensive monitoring device which can indicate the presence of oxygen in a gas. The instrument described below was developed to meet a need in the argon-arc welding of stainless steel pipes, where the presence of even small amounts of oxygen was found to result in

imperfect welds. It may also be suitable for use as a monitoring device on glove-boxes when oxygen must be excluded. The apparatus consists of a glass tube containing reduced methylene blue reagent, through which is bubbled the gas being tested. When the oxygen concentration of the gas rises above 100 p.p.m. v/v the liquid develops a blue colour.

#### Apparatus and Reagents

The apparatus (Fig. 1) consists of a Pyrex test-tube 15 cm. long, fitted with a B40 standard ground socket. Inlet and outlet tubes are sealed into a B40 cone as shown. A three-way tap is included in the inlet side and a standard tap on the outlet. The incoming gas is broken into fine bubbles by passage through a sintered glass disc.

#### Stock Solutions

- (i) 0.3% aqueous methylene blue.
- (ii) 1.0% lactose solution (to which is added a small quantity of thymol as preservative.)
- (iii) 0.1M sodium hydroxide solution.

All concentrations are approximate.

#### Indicator Solution

It has been found advisable to prepare the indicator solution daily. To 100 ml. of distilled water or tap water is added 1 ml. of each of the three stock solutions.

#### Method

100 ml. of the bright blue, freshly prepared indicator solution are placed in the test-tube and the apparatus is assembled with the taps open. The test-tube is heated by means of a bunsen burner and the contents are boiled until the methylene blue is reduced and the solution becomes colourless (about 3 min.). The heater is then removed, both taps are closed, and the apparatus is cooled to room temperature. If the apparatus is airtight no air will leak in during cooling and the indicator

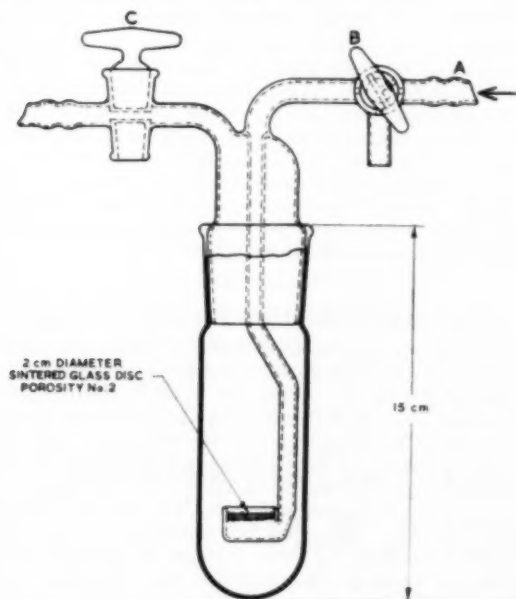


Fig. 1—Sketch of the oxygen indicating apparatus

solution will remain colourless. The apparatus is now ready for use.

The gas stream to be tested is connected to the inlet tube *A* (Fig. 1) and the three-way tap is turned so that the gas flows out through the by-pass. When the inlet tube has been flushed out, the tap *B* is turned so that the gas flows directly into the bubbler. When bubbles start to appear the tap *C* may be opened.

Gas containing less than 100 p.p.m. v/v of oxygen may be passed through indefinitely and the indicator solution will remain colourless. When the oxygen concentration of the incoming gas reaches 100 p.p.m. v/v the indicator solution will develop a faint but definite blue-green colour. As the oxygen concentration further increases, the blue colour becomes more intense.

### Experimental

The calibration procedures were carried out using electrolytically generated oxygen, known amounts of which were added to "oxygen-free" nitrogen. The amount of oxygen in the nitrogen was measured independently by use of the Hersch galvanic oxygen meter and was found to be 14 p.p.m. v/v. Details of the electrolyser and oxygen meter are given by Hersch.<sup>1</sup> Gas flow rates were measured by a Venturi flow-meter.

#### Effect of Varying Oxygen Concentrations on Indicator

"Oxygen-free" nitrogen was bubbled through the prepared indicator solution at the rate of 100 ml./min. The oxygen content of the gas was increased step-wise and the effect on the indicator was noted: the results are set out in Table I.

TABLE I.—EFFECT OF VARYING OXYGEN CONCENTRATIONS ON INDICATOR

Oxygen Concentration in Nitrogen (p.p.m., v/v)	Effect on Indicator
14	No colour developed
50	No colour developed
80	No colour developed
100	Faint, persistent greenish-blue
200	Faint blue
500	Increased intensity of blue colour
1,000	Deep blue colour (not as intense in colour as original indicator.)

#### Effect of Passage of Oxygen-free Gas through Oxidised Indicator

"Oxygen-free" nitrogen (< 20 p.p.m. v/v oxygen) was bubbled through the oxidised (blue) indicator solution, kept at room temperature, at the rate of 100 ml./min. for 18 hr. The solution was not decolourised.

#### Effect of Passage of Oxygen-free Gas through Reduced Indicator

"Oxygen-free" nitrogen (< 20 p.p.m. v/v oxygen) was bubbled through the reduced (colourless) indicator solution, kept at room temperature, at the rate of 100 ml./min. for 18 hr. The solution remained colourless.

### Discussion

Methylene blue is widely used as a redox indicator in biological studies. Its use by Thunberg in demonstrating the presence of dehydrogenases in tissues is discussed by Baldwin.<sup>3</sup> Methylene blue has also been used as the basis of other tests for the presence of oxygen in gases<sup>4</sup> and the determination of oxygen in gases.<sup>5</sup>

The test described here is based on the fact that in mildly alkaline solution, reducing sugars such as lactose are readily enolised at elevated temperatures, so that in

the concentration range used, methylene blue will be reduced by the lactose when boiled, but not in the cold.

It is evident from the experimental findings, that the device described above is suitable for the detection of oxygen in pure nitrogen in amounts of 100 p.p.m. v/v, or greater. Where interfering gases such as hydrogen sulphide may be present, a second gas bubbler containing oxidised indicator may be included in the circuit. Where interfering gases are present the oxidised indicator will be reduced in the cold.

### REFERENCES

1. Hersch, P., *Instrument Practice*, 1957, 817-833 and 937-941.
2. Robertson, A. J., "Mass Spectrometry," 1954, Methuen, p. 84.
3. Baldwin, E., "Dynamic Aspects of Biochemistry," 1948, Cambridge University Press.
4. Riemisdijk Mvan, *Nederlandsche Tijdschr. Geneeskunde*, 1922, 66, 1, 1423-7.
5. Kling, A. and Claraz, M., *Compt. rend.*, 1936, 203, 319-321.

## Measuring Hydrogen in Steels

It is generally not appreciated that a large number of common gases are soluble in solid metals, even at ordinary room temperature, and such gases can have far-reaching effects on the way in which the metals behave when subjected to forging and welding. Because of the importance of these processes, there is a growing interest in possible ways of measuring the amount of gas dissolved.

The British Welding Research Association has recently described a new rapid technique for measuring the quantity of hydrogen dissolved in steels. Hitherto, the determination of hydrogen in steel has generally been made by heating the sample to about 600-700°C. under a high vacuum, when the gas is drawn out in much the same way as dehydration of materials can be effected by a combination of heat and vacuum. The vacuum system required for this method, however, is expensive and fragile and the analysis takes quite a long time.

The new B.W.R.A. technique, which was described at a recent symposium on "Determination of Gases in Metals," organised jointly by the Iron and Steel Institute, the Institute of Metals and the Society for Analytical Chemistry, uses a carrier gas principle. In this, argon, an inert gas, is passed over the sample of steel, which is heated in a furnace. The gas evolved is swept along to a hydrogen-sensitive cell from which the result is plotted directly on to an electrical graph recorder in the form of a peak. The system is so accurate that as little as 1 p.p.m. hydrogen can be detected and measured. The analysis time with this apparatus is 15 minutes compared with about 2 hours for the more usual instrument. A patent application has been made.

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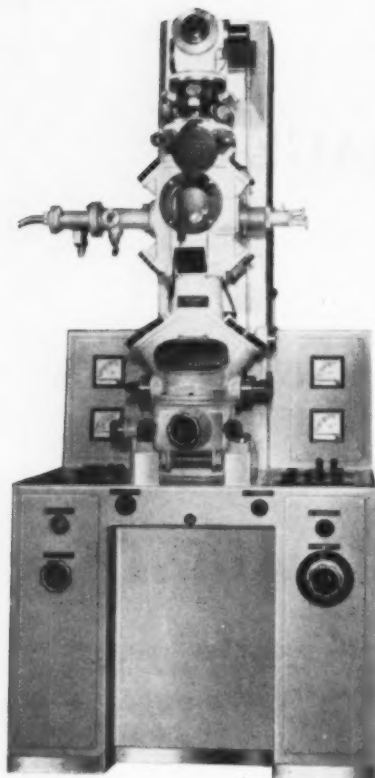
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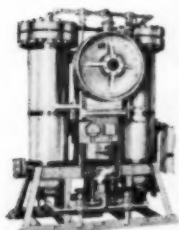
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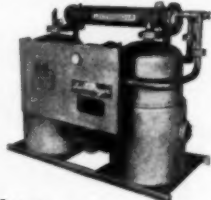
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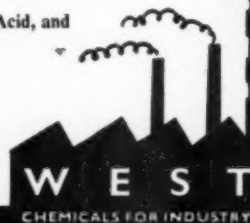
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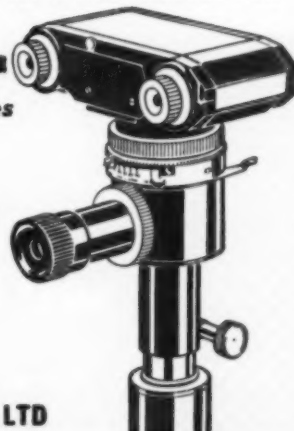
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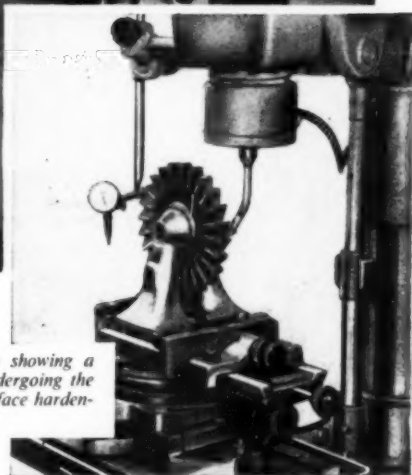
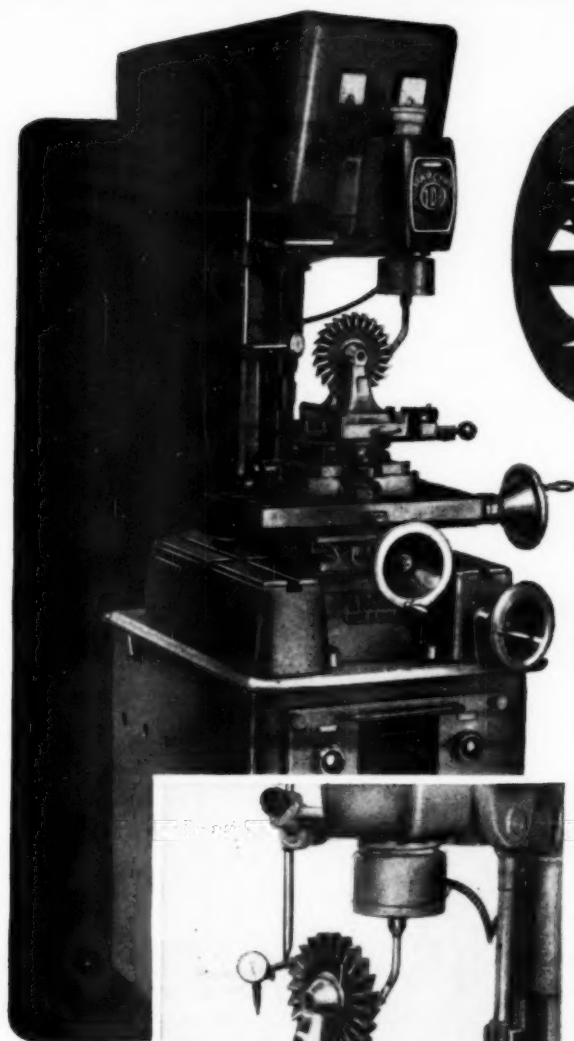
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